On the Clear Evidence of the Risks to Children from Non-Ionizing Radio Frequency Radiation: The Case of Digital Technologies in the Home, Classroom and Society

Professor Tom Butler

A TRADITION OF INDEPENDENT THINKING

UCC

University College Cork, Ireland
Coláiste na hOllscoile Corcaigh

Contents

Abstract 2

Introduction 3

Do existing Standards on Wireless Digital Technologies protect Children? 3

Why are Independent Scientific Studies more Trustworthy? ..4

What is the Reaction to the Mounting Evidence? 5

How can we make Sense of Difference of Opinion among Scientists? 5

What is the Significance of the U.S. NTP Study? 6

What is the Proof of the Potential Toxicity and Carcinogenicity of RFR? 7

What is the Evidence from Epidemiological Studies? 8

What are Implications for Childhood RFR Exposure? 11

What are the Risks to Children of RFR Exposure In Utero? .. 11

What are the Biological Mechanisms that Produce Ill-health in Children and Adults? 12

What is the Evidence that Microwave RFR Promotes the Development of Existing Cancers? 14

Why are Existing Standards Unsafe? 15

Here be Dragons! 16

Why are Children using Wifi-enabled Devices at Significant Risk? 17

Why is there Apparent Ambiguity in the Perceived Risk of Wifi RFR? 18

Why are the Risks to Children Growing? 20

What do Insurance Companies, Regulators, Telecoms Operators and Lawyers have to say about the Risks? 21

Conclusions 22

The Last Word belongs to the Philosophy of Science 26

About the Author 27

References 28

On the Clear Evidence of the Risks to Children from Non-Ionizing Radio Frequency Radiation: The Case of Digital Technologies in the Home, Classroom and Society

"The level of proof required to justify action for health protection should be less than that required to constitute causality as a scientific principle"

Professor Rainer Frentzel-Beyme MD

Abstract

Children's health and well-being is under significant threat from everyday digital technologies, as the past 15 years have seen the proliferation of microwave non-ionizing radio frequency radiation (RFR) devices and related communication systems in the home, school and society. The safety standards for such devices—smartphones, tablets etc.—and the systems that serve them, were based on the proven thermal effects of microwave radiation in adults, not children. As comprehensive research published between 1969-1976 by the U.S. Naval Medical Research Institute indicates, scientists have long been aware of equally harmful non-thermal effects—e.g. the risks of developing cancers, neurological, neurodegenerative, and other pathophysiological problems. However, physicists and engineers have operated on the theory that non-ionizing RFR could not directly damage human DNA and lead to cancer, as it was far less powerful than ionizing radiation (x-rays, nuclear etc.). That theory has been solidly and roundly refuted, as this paper illustrates. Nevertheless, industry-funded scientists continue to hold that non-thermal effects do not exist. However, thousands of independent research studies have demonstrated that low-intensity RFR elicits a range of pathophysiological conditions in experimental animals and humans. This is why parents, educators and governments should be alarmed, be better informed, and take immediate and appropriate action. This brief research review aims to inform by presenting the findings of scientific research, in a balanced, objective manner, on the risks to children. This information is based on proven scientific theories and clear empirical evidence. The paper concludes by offering practical advice on how the risks to children, and indeed adults, can be minimised.

Introduction

Children's health is at risk from everyday wireless digital technologies. Why? The past 15 years witnessed the proliferation of near-field microwave non-ionizing Radio Frequency Radiation (RFR) devices in the home, school and society. However, far-field RFR from WiFi access points (AP) and routers, and at a wider level, 2, 3, 4 and 5G cellular telecommunications antennae, also pose significant risks, as extant scientific research demonstrates.

The cumulative body of research, which includes scientific findings from laboratory experiments and epidemiological studies, provides *clear evidence* of the threats to human health and well-being from non-ionizing RFR. [1] However, the risks to the health and well-being of children was never considered when the safety standards were developed. This creates a dilemma for all, particularly for parents and educators, as the evidence on the risks to human health and well-being associated with widespread and indiscriminate exposure to RFR is clear and unambiguous, with children being particularly at risk.[2]

The figure below indicates the common far-field sources of RFR in the environment from private and public antennae. Add to this the near-field RFR from digital devices such as cell phones, smart phones, iPads, Kindles, laptops, children's toys, smart meters, wearable devices, and Internet of Things. Also not to be ignored are Bluetooth devices.

Do existing Standards on Wireless Digital Technologies protect Children?

The telecommunications industry and the Big Tech sector, related industry associations, regulators on both sides of the Atlantic, and standards bodies such as the Institute of Electrical and Electronics Engineers (IEEE), and the International Commission on Non-ionizing Radiation Protection (ICNIRP), focus exclusively on providing safety standards for the thermal effects of RFR. They effectively ignore or deny the existence of non-thermal effects.[3,4]

In the US, the significant clinical and biological effects of RFR were identified by naval researchers in their review of Soviet and Eastern-Bloc studies at a symposium in 1969.[5] Subsequently, in 1976, the US Naval Medical Research Institute published a bibliography of 3,700 scientific papers on the thermal and non-thermal biological

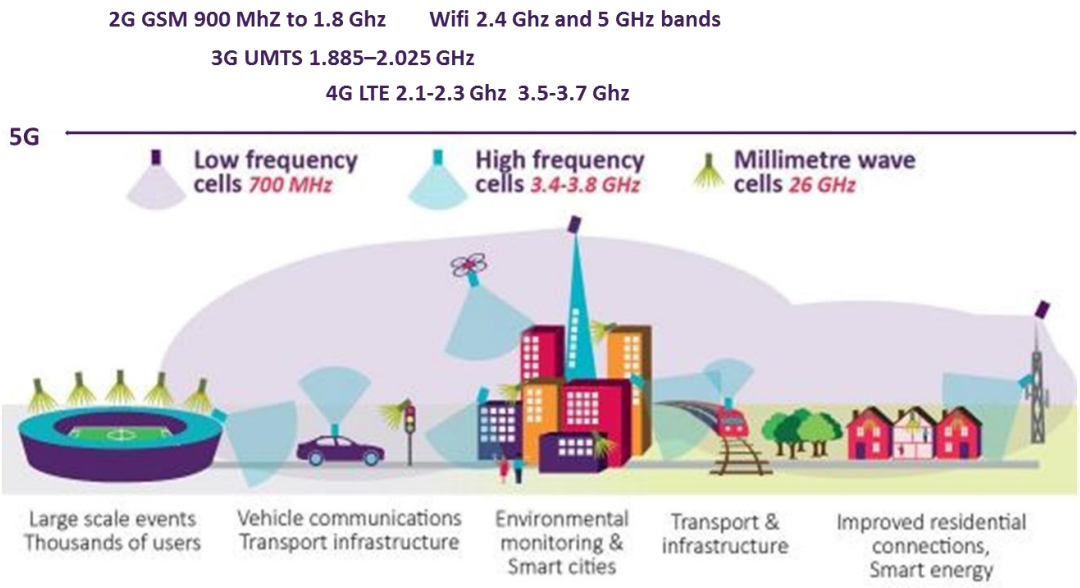

2G GSM 900 MhZ to 1.8 Ghz
Wifi 2.4 Ghz and 5 GHz bands
3G UMTS 1.885–2.025 GHz
4G LTE 2.1-2.3 Ghz 3.5-3.7 Ghz
5G
Low frequency cells 700 MHz
High frequency cells 3.4-3.8 GHz
Millimetre wave cells 26 GHz
Large scale events Thousands of users
Vehicle communications Transport infrastructure
Environmental monitoring & Smart cities
Transport & infrastructure
Improved residential connections, Smart energy

Figure 1 From 2G to 5G: RFR Unseen, Unheard, Untouched and Not Understood

effects of RFR[6]: this was the last of a series of supplements to the original report in 1972.[7] The body of scientific evidence on the health implications of the non-thermal effects of RFR has grown exponentially since.

As with the tobacco industry before it, the telecommunications industry has busy challenging all scientific findings that identify health risks with wireless technologies. Not only does it have a convenient lacuna, when it comes to the body of research prior to 1976, it has been pushing back, conducting its own studies, some, but not all, of which deny the existence of non-thermal effects. However, has a record of conveniently burying its own inconvenient truths. No pun intended, but the telecoms industry has taken a leaf out of the tobacco industry handbook when countering independent studies or explaining away research findings dating back to the 1930s viz. "A demand for [more] scientific proof is always a formula for inaction and delay and usually the first reaction of the guilty … in fact scientific proof has never been, is not and should not be the basis for political and legal action."[8] The same playbook was employed by the oil and coal industries when it came to global warming. One can see similar demands for more evidence and studies as the telecommunications industry and its funded scientists, particularly those in pseudo-independent bodies such as the ICNIRP, challenge the overwhelming body of independent research.

Why are Independent Scientific Studies more Trustworthy?

It is an interesting fact that independent scientific studies are two and a half times more likely to find evidence of biological effects and health risks than industry-funded studies.[9] It is also generally agreed that independent studies have greater scientific validity, due to the absence of conflicts of interest. Furthermore, Dr. Henry Lai, Professor Emeritus at the University of Washington, reports that all studies conducted between 1990 and 2017 find significant health risks such as DNA damage (64%), neurological effects (72%), and oxidative stress (90%).[10] The weight of objective scientific evidence has always indicated significant risks to human health—these risks are magnified significantly where children are concerned.

In 2012, Dr. Ben Goldacre published *Bad Pharma*. In a devastating evidence-based treatise on the pharmaceutical industry, Goldacre concluded:

"Drugs are tested by the people who manufacture them, in poorly designed trials, on hopelessly small numbers of weird, unrepresentative patients, and analysed using techniques which are flawed by design, in such a way that they exaggerate the benefits of treatments. Unsurprisingly, these trials tend to produce results that favour the manufacturer…Medicine is broken ... We like to imagine that medicine is based on evidence, and the results of fair tests. In reality, those tests are often profoundly flawed. We like to imagine that doctors are familiar with the research literature, when in reality much of it is hidden from them by drug companies …We like to imagine that regulators only let effective drugs onto the market, when in reality they approve hopeless drugs, with data on side effects casually withheld from doctors and patients."[11]

This is not the product of a conspiracy theorist, it is a factual account of industry practices by a respected researcher and medical journalist. Replace 'drugs' in this excerpt by wireless digital technologies and patients with users and it could have been written to describe the activities of the telecommunications industry. Regulators in this industry, such as the FCC, are as ineffective as the Food and Drug Administration (FDA) or their European counterparts. Large corporations and telecommunication companies, from Apple to Samsung, Cisco to Vodafone, lobby governments for favourable 'safety' standards for their devices and equipment. They use their market power to keep the status quo. They bury safety notices in the

small print or omit them altogether. They know the risks and they do not care about our children or grandchildren. Recent 'phone-gate' scandals in France and the U.S. bear testament to an industry that cannot be trusted to self-regulate.[12,13]

The non-thermal effect 'denial problem' exists because of the multi-trillion dollar commercial and economic value of wireless technologies, coupled with the risk of litigation. From the 1990s, this had telecommunications and related industry associations 'capture' regulatory agencies, such as the U.S. Federal Communications Commission (FCC), [14] to engage in disinformation and manipulate the press,[15] and to participate in the 'institutional corruption' of scientists, their universities, and governments.[16] The net result of this standard business-operating procedure is that humans are unknowingly exposed to health risks. Governments are willing partners in this and should be taking the side of citizens not industry interests. While politicians and policy makers behaved like ostriches, the related health risks have risen significantly with the emergence of 5G.

What is the Reaction to the Mounting Evidence?

Exposure of humans to non-ionizing radio frequency radiation (RFR) has increased dramatically over the past 20 years. Epidemiological and experimental research highlights the increased risk of pathophysiological conditions with current exposures to near field and far field sources of RFR. In light of the mounting scientific evidence, in May 2015, over 200 eminent scientists launched an international appeal to the United Nations and the WHO based on the conviction that there is a real and present danger to children, in particular, by what they consider outdated industry standards in relation to microwave radio frequency radiation.[17] By April 2018, 244 scientists had signed the appeal: "The scientific basis for their collective concern is "numerous recent scientific publications have shown that EMF [i.e. electromagnetic fields, including RFR,] affects living organisms at levels well below most international and national guidelines. Effects include increased cancer risk, cellular stress, increase in harmful free radicals, genetic damages, structural and functional changes of the reproductive system, learning and memory deficits, neurological disorders, and negative impacts on general well-being in humans."

Industry-funded scientists and the majority of those in the ICNIRP are unconcerned and see little risk, apart from thermal effects, which they say the public are protected against by extant safety standards. Believe it or not, such differences of scientific opinion have bedeviled scientific progress across all disciplines. Hence, the tendency for scientists to be biased, to cling to dominant paradigms, and resist change in the face of scientific evidence is well acknowledged,[18] and this is particularly true in relation to the wireless paradigm.[4, 14, 19] The following section will help the reader understand this contradiction better.

How can we make Sense of Difference of Opinion among Scientists?

Sir Karl Popper was the foremost philosopher of science in the 20th Century. In 17th century Europe, people believed all swans were white. However, the discovery of black swans on the Swan River in Australia, led to the understanding that Swans could be both black or white. Thus, in *The Logic of Scientific Discovery*[20] Popper argues that "no matter how many instances of white swans we may have observed, this does not justify the conclusion that all swans are white." Thus, a theory that all swans are white can be refuted by the sighting of just one black swan.[21] Applying this logic to what is the dominant paradigm on the issue of the safety of non-ionizing radio frequency radiation, just one study of the existence of non-thermal effects, is sufficient to scientifically refute the theory that there are no non-thermal effects to non-ionizing radio frequency radiation. Fortunately, there are thousands of such studies.

There is a problem here, however. As indicated by the extensive bibliography published at the U.S. Naval Medical Research Institute by Dr. Zory Glaser and his team, the significant clinical and biological effects of RFR—both thermal and non-thermal—were identified and accepted by Soviet and Eastern-Bloc scientists. However, it is clear that U.S. scientists generally accepted that there were only thermal effects. In an extensive report in 1980, this is described as a philosophical difference based, perhaps, on cold-war politics.[22] However, applying Popper's logic, Soviet, Czech and Polish researchers rightly posited the conjecture or theory that there were a range of biological effects, thermal and non-thermal—i.e. they posited the existence of white and black swans. Therefore, they instituted experiments to corroborate of refute their conjectures. However, U.S. and Western scientists argued there were only white swans, and acted accordingly. It was only when the troublesome issue of non-thermal effects was raised by the EPA[23] and the FDA[24], that industry associations and industry-funded scientists began to craft studies to undermine the non-thermal theory.

Significantly, from 1995, Dr. George Carlo directed the industry-financed Wireless Technology Research (WTR) project using $28.5m of funding. However, when the WTR findings upheld the non-thermal theory, and indicated that RFR caused genetic damage and was a probable carcinogen, they were rejected by the industry, as an inconvenient truth, and Dr. Carlo's services were immediately dispensed with. Dr. Carlo published an account of industry dishonesty and manipulation, titled "Cell Phones: Invisible Hazards in the Wireless Age: an Insider's Alarming Discoveries about Cancer and Genetic Damage".[25] This was not the only account of industry misconduct and political manipulation to occur during the 1990s.[26]

Anticipating the evidence presented in the next major section, this paper notes Dr. Ron Melnick's statement, presented in 2019, that the National Toxicology Program (NTP) study on radio frequency radiation (RFR) "was designed to test the (null) hypothesis that cell phone radiation at non-thermal exposure intensities could not cause adverse health effects, and to provide dose-response data for any detected toxic or carcinogenic effects." [27] He states unequivocally that the null hypothesis has been falsified, in a Popperian sense, and the link with cancer proven beyond all doubt. In their analysis of previous human epidemiological studies with the findings of the NTP research, Swedish scientist oncologists Lennart Hardell and Michael Carlberg "conclude that there is clear evidence that RF radiation is a human carcinogen, causing glioma and vestibular schwannoma (acoustic neuroma). There is some evidence of an increased risk of developing thyroid cancer, and clear evidence that RF radiation is a multi-site carcinogen."[28] The scientific significance is unequivocal and proves without a shadow of doubt that the black swans of non-thermal effects are very real indeed.

Thus, we can see that what physicist and philosopher of science Thomas Kuhn referred to as a scientific revolution and paradigm change[29] is well underway in the scientific fields dealing with the risks to human health posed by RFR. However, vested interests—industry, political and scientific—in the dominant paradigm are resisting. Unfortunately, children will bear the health costs, now and into the future, of this latest paradigm war. The following sections answers key questions that will help the reader understand better the risks that non-ionizing radio frequency radiation presents to the general population, and particularly children.

What is the Significance of the U.S. NTP Study?

The game-changing study by the National Toxicology Program's (NTP) at the U.S. Department of Health and Human Services is the point of departure for the remainder of this paper's review of the scientific research on mobile and wireless RFR.

In 1999, the US Food and Drug Administration's (FDA) Center for Devices

and Radiological Health commissioned the National Toxicology Program study on the potential toxicity and carcinogenicity of RFR. [30] The FDA's concerns followed the emergence and widespread use of first generation cell phone devices in the early 1980s and second generation (2G) systems in the 1990s. The health focus and associated safety standards were, and still are, centred on the thermal effects (i.e. heating of tissues from microwaves) and not on the non-thermal effects. To be sure, the findings of extant research at the time were mixed, with no clear evidence either way of potential negative health implications of low-intensity RFR, especially where cancer was concerned.[31]

On November 1st 2018, the final report of a 10-year $30m comprehensive study by US National Institute of Environmental Health Sciences' National Toxicology Program (NTP) confirmed that radio frequency radiation (RFR) from 2G and 3G cell phones caused cancer in animals. [32] That study clearly refutes the long-held theory that non-ionizing radiation, such as RFR, cannot cause cancers or lead to other effects on the health and well-being of humans.[33]

The findings of this study opens an ethical Pandora's Box for mobile phone companies and BigTechs such as Apple, Facebook, Google and others, as the use of microwave RFR technologies underpin their business models. Furthermore, the NTP adds *"5G is currently emerging and will eventually overtake the existing 2G, 3G, and 4G technology. In the meantime, consumers will continue to be exposed to RFR from these sources in the 700-2700 MHz range. As the 5G network is implemented, some of the signals will use the same lower frequencies as the older technology previously studied by NTP. Additionally, concern has been raised because the 5G network will also use higher frequencies, up to 60,000 MHz, thereby exposing wireless consumers to a much broader spectrum of frequencies. The higher frequencies, known as millimeter waves, can rapidly transmit enormous amounts of data with increased network capacity compared to current technologies…NTP is currently evaluating the existing literature on the higher frequencies intended for use in the 5G network and is working to better understand the biological basis for the cancer findings reported in earlier studies on RFR with 2G and 3G technologies."*

What is the Proof of the Potential Toxicity and Carcinogenicity of RFR?

In 2011 the IARC classified WiFi and microwave radiation from cordless and mobile phones as a ***possible*** Class 2B carcinogen. While the findings of epidemiological studies have been debated, and chiefly focus on the long-term development of brain tumours, a recent review of such studies is unequivocal and states that *"[m]obile phone radiation causes brain tumors and should be classified as a **probable** human carcinogen (2A)"* by the WHO's International Agency for Research on Cancer (IARC).[34] However, the new evidence presented herein has scientists conceding that it should be reclassified as a Class 1 human carcinogen.

In the press release accompanying the NTP Final Report, Dr. John Bucher, Senior Scientist, at the National Toxicology Program *stated, "We have concluded that there was clear evidence that male rats developed cancerous heart tumors called malignant schwannomas. The occurrence of malignant schwannomas in the hearts of male rats is the strongest cancer finding in our study."* [35] Categorising the major findings as *"clear evidence"* is significant as this is the highest burden of proof in a scientific study by the NTP. It employs 4 levels of evidence. Other findings were categorised as *Some Evidence* (brain tumours such as glioma and adrenal gland tumours) and *Equivocal* (cancers of the prostate and pituitary glands). None of the findings were at level 4, No Evidence. The paper discusses these findings in the context of previous research.

The NTP study was not the first of its kind—it confirms the findings of previous research on the links between near field RFR exposure and various cancers—it is the most comprehensive, however. Since 1999

when the FDA flagged the issue of potential non-thermal effects of microwave radiation in cellphones, a wealth of experimental and epidemiological research demonstrated the very real biological effects of RFR on the brain, nervous systems, hearts and testes of mammals, including humans. Cancers aside, many of these studies consistently report a range of side-effects in humans, from sleep deprivation and headaches, to neurological damage, and learning disorders.[1,3,7] The NTP study also reported that DNA damage (strand breaks) was significantly increased in the brains of rats and mice exposed to RFR. The findings also reported reduced birth weights of rat pups whose mothers were exposed to RFR, in addition to cardiomyopathy of the right ventricle in the rats studied.[36]

Dr Fiorella Belpoggi, Director of the Cesare Maltoni Cancer Research Center of the Ramazzini Institute, which had recently conducted separate research that echoed the findings of the NTP Study, took issue with the ICNIRP—"*We are scientists, our role is to produce solid evidence for hazard and risk assessment. Underestimating the evidence from carcinogen bioassays and delays in regulation have already proven many times to have severe consequences, as in the case of asbestos, smoking and vinyl chloride."*[37] In the Ramazzini Institute study, Dr Belpoggi's colleagues Falcioni et al. presented their *"findings on far field exposure to RFR [that] are consistent with and reinforce the results of the NTP study on near field exposure, as both reported an increase in the incidence of tumors of the brain and heart in RFR-exposed Sprague-Dawley rats. These tumors are of the same histotype of those observed in some epidemiological studies on cell phone users. These experimental studies provide sufficient evidence to call for the re-evaluation of IARC conclusions regarding the carcinogenic potential of RFR in humans."*[38] Again to emphasize, this study is notable as it focused on the health implications of far field RFR sources on humans living or working in the proximity of mobile phone base stations, as opposed to operating 2 & 3 G handsets near field. It is also the largest long-term study ever performed in rats on the health effects of RFR. Its findings are therefore of particular concern for those, particularly children, living near RFR sources, such as mobile phone masts or WiFi routers.

It was with the implications of all this in mind that the California Medical Association (CMA)[39] stated in 2014 that *"peer reviewed research has demonstrated adverse biological effects of wireless EMF [i.e. RFR] including single and double stranded DNA breaks, creation of reactive oxygen species, immune dysfunction, cognitive processing effects, stress protein synthesis in the brain, altered brain development, sleep and memory disturbances, ADHD, abnormal behavior, sperm dysfunction, and brain tumors."* The CMA were following the lead of the American Academy of Paediatrics, which in 2013 petitioned the US Federal Communications Commission (FCC) and to the Food and Drug Administration (FDA) to reassess safety standards to RFR in order to *"protect children's health and well-being throughout their lifetimes and reflect current use patterns."* [40] That plea has fallen on deaf ears, however.

Given the significance of the NTP findings there was a muted response from the press. Coverage from the New York Times argued that the focus on 2G and 3G technologies somehow weakened the study's findings.[41] This is a spurious argument, as 4G Smartphones are backward compatible with 2G and 3G, and from a biological perspective, of greater concern, as is 5G. More worryingly the ICNIRP decided that the findings did not provide a reason to revise current (i.e. over 21-year-old) RFR exposure standards. However, Dr. Ronald Melnick rebutted the ICNIRP analysis stating it contained several false and misleading statements.[27]

What is the Evidence from Epidemiological Studies?

After more than 20 years of widespread cell phone use, one would expect to see a rise in cancers, particularly brain tumours. The evidence here is mounting, however, as

new studies in the US note a disturbing rise in cancers of the Central Nervous System, particularly in adolescents. There is also a marked increase in other cancers and also neurodegenerative diseases such as Alzheimer's Disease.

While experimental and non-experimental case control and other epidemiological studies generally emanate from natural scientists, in 2018 two social scientists reported *"that mobile phone subscription rates are positively and statistically significantly associated with death rates from brain cancer 15-20 years later. As a falsification test, we find few positive associations between mobile phone subscription rates and deaths from rectal, pancreatic, stomach, breast or lung cancer or ischemic heart disease."*[42] This 25-year cross country analysis provides solid but indirect evidence of the link between mobile phone use and cancer. However, we need to dig deeper into the available evidence from the natural and life sciences to understand probability and causality.

The French CERENAT study is the first to be considered. It reported that *"Consistent with previous studies, we found an increased risk [of brain tumours] in the heaviest users [of mobile phones], especially for gliomas."*[43] The study found the risks were higher for temporal lobe tumours, as well as gliomas, with occupational and urban mobile phone users at highest risk.

A research review of the incidence of glioblastoma multiforme tumours in England during 1995–2015 reported a *"a sustained and highly statistically significant ASR [(incidence rate)] rise in glioblastoma multiforme (GBM) across all ages. The ASR for GBM more than doubled from 2.4 to 5.0, with annual case numbers rising from 983 to 2531. Overall, this rise is mostly hidden in the overall data by a reduced incidence of lower-grade tumours."*[44] The study did not focus on RFR as the cause, so the findings must be considered 'open to interpretation' in this regard, as other environmental mechanisms cannot be ruled out. However, the following figures are clear and unambiguous. In the UK in 1995, 553 frontal lobe tumours were diagnosed in patients, while 1231 were found in 2015. Likewise, 334 temporal lobe tumours were reported in 1995, while 994 were diagnosed in 2015. The increase in these cancers of the CNS are clear and unambiguous. The authors of this study argue that:

"The rise cannot be fully accounted for by promotion of lower–grade tumours, random chance or improvement in diagnostic techniques as it affects specific areas of the brain and only one type of brain tumour. Despite the large variation in case numbers by age, the percentage rise is similar across the age groups, which suggests widespread environmental or lifestyle factors may be responsible. This article reports incidence data trends and does not provide additional evidence for the role of any particular risk factor."

It is significant that the frontal and temporal lobes receive the greatest exposure to RFR from smartphones and tablets.

A comprehensive review of the incidence of primary brain and other central nervous system tumors diagnosed in the United States during the period 2009–2013, found quite small, but statistically significant increases in some categories of CNS tumours and none in others.[45] To be sure, in this study published in 2016, the increase in the incidence of tumours reported were not as alarming as those in the UK study. However, this is only the first in a series demonstrating an upward trend.

A related U.S. study echoed the US findings, but found an *"an increasing medulloblastoma incidence in children aged 10–14 years."*[46] Another recent study on children found statistically-significant changes in several sub-types of CNS cancers, notably gliomas, in the period 1998-2013. [47] The latter study concluded that *"Continued surveillance of pediatric CNS tumors should remain a priority given their significant contribution to pediatric cancer deaths."*

In keeping with studies that provide compelling evidence for concern, a recent review study of epidemiological studies on brain and salivary gland tumours in relation to mobile phone use found the cumulative evidence to be inconclusive, but indicated that such cancers may have a long latency (i.e. greater than 15 years) and clear evidence may emerge in the future. Nevertheless, scientists argue that childhood use of RFR devices is of significant concern.[48] There is also evidence that RFR from cell phones may be triggering breast cancer in young women who carry their devices on or near their breasts.[49] In addition, extensive studies by the Hardell Group demonstrate increases in cancers of the CNS in Sweden.[50] These findings have been recently replicated in Denmark.[51]

However, more recent studies continue to ring alarm bells. A new study in The Lancet Neurology reports that "CNS cancer is responsible for substantial morbidity and mortality worldwide, and incidence increased between 1990 and 2016. Significant geographical and regional variation in the incidence of CNS cancer might be reflective of differences in diagnoses and reporting practices or unknown environmental and genetic risk factors. Future efforts are needed to analyze CNS cancer burden by subtype."[52]

In a general context, the U.S. Center for Disease Control and related research finds that non-Hodgkin lymphomas, central nervous system tumors (including brain cancers), renal, hepatic and thyroid tumours have increased recently among adolescent Americans.[53, 54] Many scientists are concerned and conclude that microwave radio frequency radiation has a significant role to play.

Take, for example, a senior epidemiologist at US healthcare provider Kaiser Permanente, Dr. De-Kun Li, believes that while the increase in brain tumors is worrisome, increases in colorectal cancer is even more troubling, particularly as he believes microwave radio frequency radiation is implicated. In 2019, the journal Cancer described a rising incidence of colorectal cancer among young Americans, with rectal cancers being slightly higher than colon cancers.[55] Another contemporary study found significant increases in colorectal cancer among people under 50 in Denmark, New Zealand, and the UK since 2009.[56] Yet another study of colorectal cancer in young adults in 20 European countries over the last 25 years found that over the last 10 years, the incidence of colorectal cancer increased 8% per year among people in their 20s, by 5% for people in their 30s, and by 1.6% for those in their 40s.[57] Dr. De-Kun Li maintains that "When placed in trouser pockets, the phones are in the vicinity of the rectum and the distal colon and these are the sites of the largest increases in cancer." While phones go into standby mode where telephone calls are concerned, most young people have WiFi, Bluetooth and 4G data enabled. This increases the level and incidence of exposure, as their apps keep their smartphones active on a continuous basis. Thus, other environmental, diet and lifestyle factors aside, wireless microwave radio frequency radiation is strongly implicated as a direct or indirect (e.g. co-carcinogen) in this latest 'uptick' in cancers.

Again the weight of the scientific evidence is considerable. If the findings of the above studies are accurate and generalizable, then the rates for frontal and temporal lobe tumours may increase significantly, as they more than doubled over a 20-year period in the UK,[44] or increase in line with high RFR exposure,[19] as RFR is now accepted as either a causal or a contributory mechanism in the occurrence of brain tumours and other cancers.[27, 28, 34, 38, 42, 43]

Few studies take into account is that the number of RFR sources has increased dramatically throughout the home, school and work environments over the past 10 years, with WiFi routers, 2-4G enabled tablets, the proliferation of WiFi enabled devices and wearables, and the number of mobile phones per person.[1]

[1] It is significant that 4G, 5G and WiGi 2.4 G-5G use Orthogonal Frequency Division Multiplexing OFDM

To compound matters even further, one of the significant findings of the NTP study was the presence of RFR promoted the growth of tumours caused by other carcinogens.[32, 33] The findings of the cumulative body of research are objective, and particularly disturbing where children are concerned. Rigorous experimental studies on laboratory rats have found that daily exposures to low-levels of microwave radiation, such as that emitted by WiFi devices, causes significant biological changes in a range of major organs such as the brains, hearts, reproductive systems, and eyes of the rats being studied.[58]

What are Implications for Childhood RFR Exposure?

All this has profound implications for the increasing numbers of children and adolescents exposed to RFR on a daily basis. And the risks to children are considerable: *"Because cells are rapidly dividing and organ systems are developing during childhood and adolescence, exposure to carcinogens during these early life stages is a major risk factor for cancer later in life. Because young people have many expected years of life, the clinical manifestations of cancers caused by carcinogens have more time in which to develop during characteristically long latency periods."*[59] A recent study demonstrated that in a child's brain the hippocampus and hypothalamus absorb 1.6–3.1 times the microwave energy of an adult brain. The absorption rate is 2.5 times higher than an adult's where a child's cerebellum is concerned. The same study found that the bone marrow in a child's skull absorbs microwave radiation at a level 10 times greater than that of an adult.[60] In addition, a child's eyes absorb higher levels of microwave radiation than adults.[61] If, as the latest scientific evidence indicates, low-level microwave radiation poses a health risk, and if safety standards are outdated, then it is logical to assume that children are at significant risk from any device radiating microwave radiation.[62]

What are the Risks to Children of RFR Exposure In Utero?

A prospective cohort study of 913 pregnant women conducted by Dr. De-Kun Li and his team at US healthcare provider Kaiser Permanente examined the association between high levels of exposure to low-frequency and high-frequency electromagnetic fields (EMF), particularly microwave RFR, and the risk of miscarriage. After controlling for multiple other factors, women who were exposed to higher EMF levels had 2.72 times the risk of miscarriage (hazard ratio = 2.72, 95% CI: 1.42–5.19) than those with lower exposures. The increased risk of miscarriage was consistently observed regardless of the EMF sources.[63] However, follow-up studies on children born to mothers with the same high levels of exposure found that in-utero exposure was related to increased risk in children of the following conditions:

- Asthma 2.7 times;
- Obesity 5 times;
- ADHD 2.9 times. [64, 65]

Research conducted at Professor Hugh Taylor's research laboratory at Yale comments on the significant increase in the incidence of ADHD. Taylor and his team posit that one or more environmental factors are involved. The paper showed that prenatal in-utero exposure of pregnant mice to real cell phone RFR produced three highly statistically significant changes observed in mice exposed in-utero. These are: (1) a decrease in memory function; (2) hyperactivity; and (3) an increase in anxiety. The researchers conclude "that these behavioral changes were due to altered neuronal developmental programming."[66]

These results have been replicated in several subsequent experimental studies on

---

with pulsed microwave RFR signals. Research cited herein found that this type of RFR has the greatest impact on biological systems, whether it is rats, mice or humans.

rodents.[67, 68, 69] However, there are also a number of epidemiological studies that identify similar outcomes in children.[70,71]

These studies provide evidence for an association between prenatal exposure to cell phone RFR and the development of ADHD. Clearly, this is a complex matter, made even more so by the fact that there was no hope of a paradigm change, until the 'smoking gun' provided by the NTP study removed any doubt that RFR can act directly, via identified mechanisms, to induce tumours in biological organisms exposed to radiation levels within those permitted by existing standards and to which users are typically exposed. This should stimulate a reassessment of the risks in relation to all RFR use, particularly children, as *"[t]he level of proof required to justify action for health protection should be less than that required to constitute causality as a scientific principle"*.[72] We are far beyond that level of proof where RFR is concerned.

What are the Biological Mechanisms that Produce Ill-health in Children and Adults?

While the direct effects of certain carcinogens are widely acknowledged, research illustrates that *"carcinogens may also partly exert their effect by generating reactive oxygen species (ROS) during their metabolism. Oxidative damage to cellular DNA can lead to mutations and may, therefore, play an important role in the initiation and progression of multistage carcinogenesis…Elevated levels of ROS and down regulation of ROS scavengers and antioxidant enzymes are associated with various human diseases including various cancers. ROS are also implicated in diabetes and neurodegenerative diseases"*[73].

Research on mobile phone RFR and WiFi pulsed microwave signals have demonstrated that they produce elevated levels of reactive oxygen species (ROS), which in turn cause oxidative stress in cell.[74,75, 76] Oxidative stress is caused by an imbalance between ROS and the counter effects of antioxidants that help detoxify and repair biological systems. Thus, the body normally employs antioxidant defence mechanisms to counter ROS and help avoid diseases such as cancer, which are trigged by oxidative stress and its tendency to cause strand breaks in a cell's DNA.

A raft of studies indicate that a chain of biological mechanisms produces the observed negative health outcomes in laboratory animals and humans. Martin Pall, Professor Emeritus of Biochemistry and Basic Medical Sciences, Washington State University points to the role of voltage-gated calcium channel (VGCC) activation, which is triggered by RFR sources such as 2-5G and WiFi, as being one of primary causal mechanisms.[77]

In his review published in 2018, Professor Pall cites over 120 empirical research papers in support of his thesis. Thus, this is further support for the cumulative body of evidence which refutes the proposition that RFR has no biological effects, other than local thermal effects on tissue. Professor Pall's earlier 2013 review paper cites 22 research studies that specifically point to the role played by VGCC activation.[78] The number of studies replicating experiments that corroborate this theory has grown significantly, while none appear to refute it. Figure 1 illustrates the posited mechanisms, pathways and outcomes. A detailed discussion is beyond the scope of this paper, however, several important mediating mechanisms and pathophysiological outcomes are now discussed.

A review of scientific studies by Kesari et al. in 2013 concluded that relatively brief, regular, and also long-term use of microwave devices resulted in negative impacts on biological systems, especially the brain.[79] This review by Kesari et al. squarely highlights the role played by reactive oxygen species (ROS) as a key mechanism (generated by exposure to microwaves) in producing serious negative effects in living organisms. Exposure to ionizing radiation has been long known to disturb the balance between ROS and the

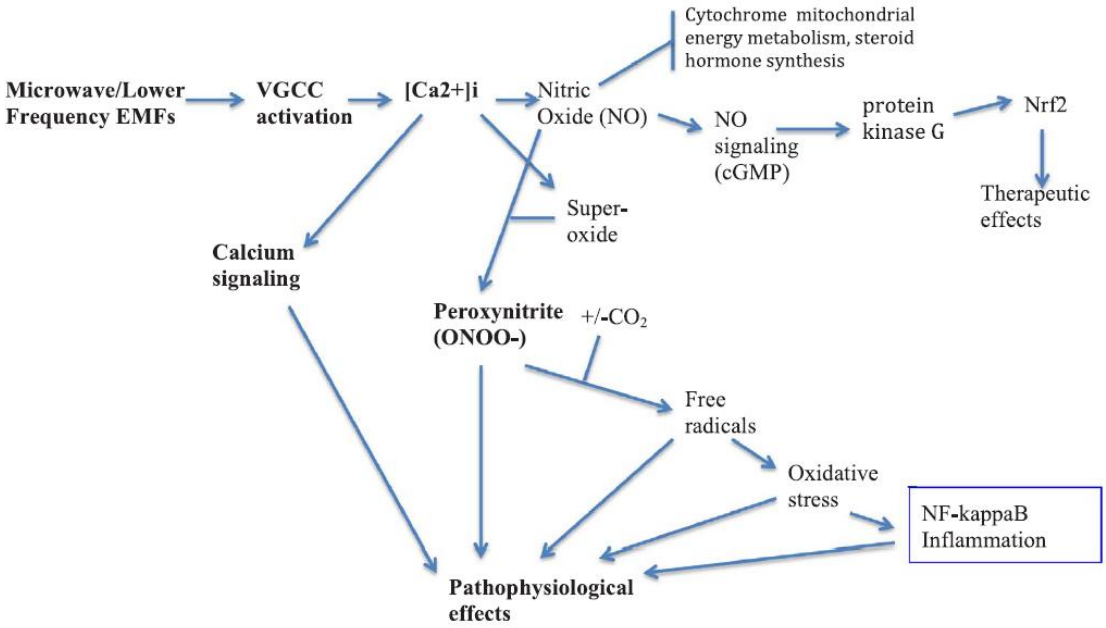


Figure 2 Mechanisms and Pathways to Pathophysiological Effects (Reproduced from Pall 2018)

antioxidants that neutralise them. Usually this imbalance results in a high probability that the subject will develop cancers and other chronic conditions. A wealth of studies now illustrate, however, that non-ionizing radiation emitted from smart phones, cordless phones, WiFi, Bluetooth and other wireless technologies, such as those powering the Internet of Things (IoT) can severely disturb this balance also, by amplifying ROS, suppressing antioxidants, and increasing oxidative stress. There is substantial evidence that oxidative damage to cellular proteins, lipids and DNA is at the root cause of many of the ill-effects of microwave RFR. Most worrying in all of this is that scientists have found that the mutagenic effects on the DNA of living cells occurs under low-levels of exposure to the pulsed microwave radiation found in most of these devices. (This is discussed below in some detail.) The consequences for children are obvious, given their greater exposure levels and susceptibility to health ill-effects and also that their bodies are constantly growing and developing.[80, 81]

A recent study illustrates relatively low level of exposure required to produce adverse biological effects. Chauhan et al.[58] published the results of their experiment on Wistar rats in 2016. The rats in this experiment were exposed to RFR at 25% of the normal level at the human ear and 15% of the level when carried for 2 hours per day for 35 days. Autopsies of the rats exposed to RFR revealed significantly high levels of ROS in the livers, brains and spleens of the exposed animals. In addition, histological changes were also found in brains, livers, testes, kidneys and spleens. In line with a wealth of other similar studies, the researchers concluded that the *"results indicate possible implications of such exposure on human health."* Earlier studies found that rat brains exposed to RFR exhibited an increase in single strand DNA breaks and chromosomal damage in brain cells. Thus, it is beyond doubt that the substantial increase in ROS in living cells under RFR at low signal strength could be causing a broad spectrum of health disorders and diseases, including cancer, in humans and particularly in children. Certainly, recent studies have provided significant empirical evidence to support this theory.

Another recently discovered mechanism found to affect the growth of glioblastoma multiforme tumours in humans is the p53 protein. [82] Glioblastoma are the most common and most malignant of the glial tumours found in the brain and central nervous system.[44] Akhavan-Sigari et al. studied 63 patients with this type of tumour and found that patients that used *"mobile phones for ≥3 hours a day show a consistent pattern of increased risk for the mutant type of p53 gene expression in the peripheral zone of the glioblastoma, and that this increase was significantly correlated with shorter overall survival time."* [84] This is a significant finding.

More worrying is a recent study conducted on the Swedish National Inpatient Register: *"The main finding in this study was increasing rate of brain tumor of unknown type in the central nervous system."* [83] The research being conducted by the 'Hardell Group' in Sweden, which is responsible for this study, has consistently demonstrated a link between mobile phone use and cancer. Two recent studies from the group confirm the link between RFR and cancers in humans. In the first, both mobile and cordless phones were associated with an increased the risk of glioma, a type of brain tumour. [84] It found that the *"First use of mobile or cordless phone before the age of 20 gave higher OR [odds ratio] for glioma than in later age groups."* Which indicates that children or teenagers are at significant risk. In the second, researchers found that the rise in thyroid cancers in Sweden was linked with increase in exposure to RFR. [85] To be sure, epidemiological studies such as the latter are akin to looking for a needle in a haystack, and are criticised by some as being flawed, however their findings need to be viewed in a new light given the scientific evidence emerging from laboratory experiments such as the NTP study.

Dr Christopher J. Portier, Associate Director, National Institute of Environmental Health Sciences and Director, Office of Risk Assessment Research, co-authored an article with Dr Wendy Leonard in *Scientific American*, following the initial release of the NTP study findings in 2016. They conclude that, *"Cellphones probably cause cancer if the exposure is close enough, long enough, and in sufficient magnitude. We don't yet know the risk for a given level of exposure in humans. We need more data in this area, not only for cellphones, but for bluetooth devices, WiFi and all the other RF-EMF devices out there. Until then, reduce your exposure whenever possible."* [86] Arguments presented earlier, and also in the concluding sections of this paper, indicate that there is sufficient scientific evidence to halt any further deployment of wireless technologies in the environment, due to the nature of the risks posed.

What is the Evidence that Microwave RFR Promotes the Development of Existing Cancers?

One important recent finding is that RFR has cocarcinogenic effects. In research published in 2010, carcinogen-treated mice exposed to RFR demonstrated significant tumour-promoting effects. [87] A study by Lerchl et al. in 2015 replicated the earlier study using higher numbers of animals in both the control and experimental groups. [88] Lerchl et al. confirmed and extended the previous findings. They report that numbers of tumours of the lungs and livers in exposed animals in were significantly higher than in the control groups. They also reported significantly elevated lymphomas through RFR exposure. The scientists hypothesized that cocarcinogenic effects may have been *"caused by metabolic changes due to exposure."* It is significant, and extremely worrying, that tumour-promoting effects were produced *"at low to moderate exposure levels (0.04 and 0.4 W/kg SAR), thus well below exposure limits for the users of mobile phones."* The authors conclude that their *"findings may help to understand the repeatedly reported increased incidences of brain tumors in heavy users of mobile phones."* The mechanisms presented in the previous section help explain why and how RFR exposures induce the observed findings in these and other studies.

Why are Existing Standards Unsafe?

The existing standards for mobile (2,3, & 4G) and WiFi are considered unsafe. 5G technology increases the risk considerably, as Professor Martin Pall indicates in his new research monograph *5G Risk: The Scientific Perspective*.

The US Federal Communications Commission (FCC) mandates that *"The safe limit for a mobile phone user is an SAR of 1.6 watts per kg (1.6 W/kg), averaged over one gram of tissue, and compliance with this limit must be demonstrated before FCC approval is granted for marketing of a phone in the United States."* Surprisingly the safe limit in the EU is 2 W/Kg, a much weaker standard of protection. Here the EU follows the International Commission on Non-Ionizing Radiation Protection (ICNRP) standard set in 1998. This based on decades old–1970s and 1980s—studies of limited relevance to humans, and children in particular.

SAR is the Specific Absorption Rate. Expressed in Watts (a unit of electrical power) per kilogram of human tissue, SAR measures of the rate at which RFR energy is absorbed by the human body. In the testing procedures the FCC uses to certify that cell phones don't exceed the 1.6 *W/kg* SAR limit, the devices are tested 0.59 inches and 0.98 inches (1.5cm to 2.5cm) from the body. Hence, smartphone manufacturers provide these guidelines buried in their safety information. If users operate their devices within these limits, which most do, they are in breach of the safe operating limits and are more at risk from both thermal and non-thermal effects. To make matters worse, 75% of smartphones regularly exceed FCC safety limits, as a recent correspondence between Washington DC law firm, Swankin & Turner, who sent a letter to the FCC indicates. The letter questioned whether the agency adequately enforced its cell phone radiation exposure limits. [89] This claim was confirmed by research performed on behalf of The Chicago Tribune.[13] This situation is even worse in the EU, as the recent report from the French regulator indicates. The Agence Nationale des Fréquences (ANFR) revealed that 9 out of 10 phones across all manufacturers exceeded the manufacturer's reported radiation test levels in positions other than the head and where the phone is in contact with the body. [90] This revelation does not inspire confidence in with the regulator, who initially refused to disclose the findings, nor the industry. Indeed, it is significant that research sponsored by *The Chicago Tribune* in 2019 discovered that Apple and Samsung smartphones breached FCC regulations significantly.[13] This resulted in a Class Action against Apple in the US.

If a smartphone is on, but not being used for calls, text, or to browse online, it still communicates with cell phone base towers to maintain internet access. This allows app notifications, instant message texts, updates, and so on. So your phone is never off. Hence, when you carry it in your pockets or on a belt wallet, it's not being operated within the safe distance and the phone manufacturer is not liable. Note that the safety limits for cell phones and WiFi focus on thermal effects only. Remember also that non-thermal effects have been observed at much lower SAR levels from individual devices and also cellular base stations and WiFi router.[1]

Russian scientist Dr. Yuri Grigoriev, Chairman of the Russian National Committee on Non-ionizing Radiation Protection (RNCNIRP) points out that *"National and international regulatory limits for radiofrequency radiation (RFR) exposure from cell phones and cell towers are outdated."* [91] He argues that Western standards are inadequate to protect human health, in contrast with those in Russia, especially where the health of children is concerned. In Belpomme et al. study[1], whose authors include cancer researchers, it is argued that *"In spite of a large body of evidence for human health hazards from non-ionizing EMFs at intensities that do not cause measureable tissue heating, summarized in an encyclopaedic fashion in the Bioinitiative Report (www.bioinitiative.org), the World Health Organization (WHO) and governmental agencies in many countries have not taken steps to warn of*

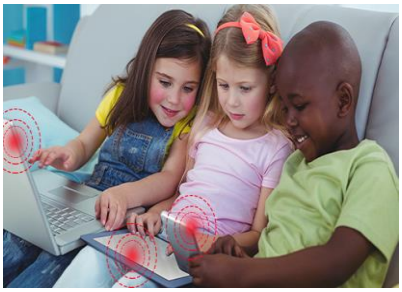
the health hazards resulting from exposures to EMFs at low, non-thermal intensities, nor have they set exposure standards that are adequately health protective."

Here be Dragons!

The industry safety standard for WiFi was established in 1996 by the FCC. It adopted the IEEE standard for safety levels with respect to human exposure to radio frequency electromagnetic fields, 3 kHz to 300 GHz, of 1991, which was based on that issued by the National Council on Radiation Protection (NRCP) in 1986. This standard covers only the thermal hazards from RFR. The hazards covered by the FCC standard are based on the specific absorption dose-rate (SAR) that produces thermal effects in body tissue. As indicated SAR is typically measured in Watts/Kilogram. So, put simply, SAR estimates the amount of energy absorbed by a human body or part thereof when exposed to an RFR signal. While accurate, it chiefly focuses on thermal effects of RFR. The FCC guidelines are based on a 4 W/Kg adverse level effect observed in laboratory animals. This excerpt from the Code of Federal Regulations (CFR 47/2.1093) is instructive:

"The SAR limits for general population/uncontrolled exposure are 0.08 W/kg, as averaged over the whole body, and a peak spatial-average SAR of 1.6 W/kg, averaged over any 1 gram of tissue (defined as a tissue volume in the shape of a cube). Exceptions are the parts of the human body treated as extremities, such as hands, wrists, feet, ankles, and pinnae, where the peak spatial-average SAR limit is 4 W/kg, averaged over any 10 grams of tissue (defined as a tissue volume in the shape of a cube). Exposure may be averaged over a time period not to exceed 30 minutes to determine compliance with general population/ uncontrolled SAR limits."

Based on existing theories and research data, the FCC recognised the safety problems with WiFi and ***recommended that such devices are not operated less than 20 cm from the human body for 30 minutes***. However, as far back as 2002, the Environmental Protection Agency (EPA) stated that the *"FCC's exposure guideline is considered protective of effects arising from a thermal mechanism but not from all possible mechanisms. Therefore, the generalisation by many that the guidelines protect human beings from harm by any or all mechanisms is not justified"*[92]. The EPA's reservations were justified, given research findings published over the past 17 years (to 2019) that refute the theory that hazards were confined to thermal effects.



When is laptop not a laptop? When it's WiFi-enabled. Such devices must be 20 cm or 8" from the body— an

We might add that at the time, the FCC never envisaged adults carrying WiFi enabled devices on their person, and certainly never envisaged children using these devices on a regular basis. Note too that adults and children carry WiFi-enabled smartphones on their person, less than 1 cm from their bodies and well within the 20 (8") cm limit of safe operation. This is also true when they make WiFi-enabled WhatsApp and Skype calls. However, today such devices are in widespread daily use by children across developed countries. Furthermore, given the observable patterns of use, the 30-minute maximum exposure is being breached on a regular basis by both adults and children. Thus, given the scientific evidence, it is troubling to think that children are carrying or operating WiFi devices on or near their person, breaching the safety guidelines set by the FCC, and

for periods much, much longer than 30 minutes.

Opposing views come from the BigTech and telecommunications companies, who like the tobacco lobby before them, are arguing that there is no danger in using WiFi technology or mobile phones. This view is based on the aforementioned belief that non-ionizing radiation such as microwaves are not powerful enough to cause damage to human DNA. However, as Professor Martin Pall concludes *"Repeated Wi-Fi studies show that Wi-Fi causes oxidative stress, sperm/testicular damage, neuropsychiatric effects including EEG changes, apoptosis, cellular DNA damage, endocrine changes, and calcium overload."*[77]

Why are Children using WiFi-enabled Devices at Significant Risk?

All WiFi devices available in Europe are FCC compliant. FCC guidelines propose a maximum power density of 10 W/m^2 or 1,000 μW/cm^2.[93] Note that this maximum power density protects from thermal or heating health effects only. All wireless devices used in the US go through a formal FCC approval process to ensure that the maximum allowable level when operating at the device's highest possible power level does not exceeded. Recent events indicate that self-regulation by the industry is, however, ineffective and devices regularly break FCC limits.[94]

In contrast to the FCC and European regulatory agency thermal safety levels, the European Academy for Environmental Medicine (EUROPAEM) EMF Guidelines (2016) indicates a non-thermal safety level of 10 μW/m^2 or 0.001 μW/cm^2 daytime exposure and 1 μW/m^2 nighttime, with 0.1 μW/m^2 being the limit for sensitive populations. [95] This is 1,000,000 to 100,000,000 times less, in terms of permitted exposure, than the FCC Guidelines. The EUROPAEM guidelines focus on for the prevention, diagnosis and treatment of EMF-related health problems and illnesses, and are based on the Austrian Medical Association Guidelines. However, the precautionary exposure guidelines recommended in the Bioinitiative Report stands at a more stringent 3–6 μW/m^2.[96] Clearly children are included in the sensitive categories as are the fetuses being carried by pregnant women.

A research report on WiFi in the classroom in 2000 by Dr. Bill Curry answers the question 'what is the exposure of children in a WiFi-enabled classroom when using WiFi devices?'[97] Dr. Curry is a highly experienced physicist, and is both conservative and meticulous in applying accepted theory and formulae in his calculations.

As indicated, there is a significant body of scientific evidence on hazardous non-thermal levels of microwave radiation. EUROPAEM research demonstrates that the safe exposure for a normal adult is 10 μW/m^2 when exposed to Wi-Fi 2.4 GHz. The safe level for children is obviously much less. [2] Beyond this level there is a risk of non-thermally generated biochemical molecular interactions that lead to oxidative stress, among other health ill-effects. Dr. Curry conservatively estimates from his data that in a typical classroom scenario, "that any one child will receive a radiation dose commensurate with a radiation density of at least 6 - 8 μW/cm^2, perhaps even more." We have noted that EUROPEAM's safe level of adult exposure is 10 or 0.001 μW/cm^2. Hence, 10,000 μW/m^2 = 1 μW/cm^2. Thus, Curry's 6-8 μW/cm^2 translates into 60,000-80,000 μW/m^2. That is approximately 6,000-8,000 times higher than the recommended safe exposures for adults as per EUROPEAM, or up to 15,000 higher that the Bioinitiative guidelines. However, if a child's health is compromised, this exposure could be up to 800,000 times the safe level recommended by EUROPEAM. It is significant that when Dr. Curry conducted his study, there was no recommended maximum non-thermal level of exposure for adults, let alone children.

A study by URS in 2012 for the Los Angeles Unified School District [98], recommends a cautionary level of 0.1 μW/cm^2, (1000 μW/m^2) taken as a whole-body, time-averaged value. URS maintains that this "is

consistent with accepted practice." This cautionary level is 10,000 times lower than FCC regulations, and 100 times greater than EUROPEAM. It is also 60-80 times lower than the estimated actual exposure measured by DR. Curry. URS concludes that "a recommended cautionary level of 0.1 $\mu W/cm^2$ is attainable within LAUSD classrooms."[99] However, this is per device and reflects protection from thermal effects only. It says nothing about the average, cumulative exposure from ALL nearby devices and other sources.

A more recent, and perhaps realistic, study was carried out in schools in Sweden. Eighteen teachers from seven schools participated and carried body-borne exposimeters (EME-Spy 200) in school. The reported results indicate that "mean exposure to RF radiation ranged from 1.1 to 66.1 $\mu W/m^2$. The highest mean level, 396.6 $\mu W/m^2$, occurred during 5 min of a lesson when the teacher let the students stream and watch YouTube videos. Maximum peaks went up to 82,857 $\mu W/m^2$ from mobile phone uplink." As indicated, the highest mean exposure recorded on a teacher during the whole of a lesson was 396.6 $\mu W/m^2$, which is nearly 40-4,000 times the recommended EUROPEAM levels or 80 times the safe limits recommended by the Bioinitiative report.

It must be remembered that teachers were either standing at the top of the classroom or moving about the room, and not sitting in front of laptops or iPads, as students would be. Since microwave RFR and WiFi exposure levels are higher nearer an antenna source, students sitting in front of their laptops or iPads at a distance of approx. 30-40 cm would have recorded higher exposures, had they been fitted with exposimeters. Thus actual student exposures would be nearer to the levels calculated by Dr. Curry, as opposed to those recorded by teachers.

It is also significant that the highest levels measured on a teacher was 82,857 $\mu W/m^2$ when he/she using a mobile phone connecting to a cellular base station. Note that the phone would possibly have been the same distance from the exposimeter, as a student's head would be from an iPad screen, into which the WiFi antennae is integrated. Note that the recorded level of 82,857 $\mu W/m^2$ from a 4G cellphone is similar to the power density recorded by Dr. Curry. Furthermore, most students today carry smartphones with 4G LTE, WiFi and Bluetooth powered on, and apps running in the background. Hence, their exposure will be potentially higher on average, as their smartphone antennae and iPad WiFi antenna, would be closer to their bodies.

There is a technical property of WiFi, which in general circumstances, indicates that the average exposure is much less than the peak exposures, but still exceeds the EUROPEAM guidelines. I now address this potentially mitigating factor.

Why is there Apparent Ambiguity in the Perceived Risk of WiFi RFR?

WiFi is the common name for Wireless Local Area Network (WLAN) IEEE 802.11 standard. This standard is complex and evolving as engineers innovate to provide higher bandwidth speeds for communication. Take for example that the 802.11a (5Ghz) and 802.11b (2.4 GHz) revisions to the 802.11 standard were introduced in 1999. While 802.11a delivered a theoretical bandwidth of 54 Mbps, 802.11b delivered a total bandwidth throughput of 11 Mbps (million bits per second). The latter became more widely adopted for technical and practical reasons. Since 802.11a, subsequent revisions to the 802.11 standard have employed Orthogonal Frequency Division Multiplexing (OFDM) technology, the same as that used in 4G and 5G telephony and broadband. The 802.11a/g revision (2003) increases the data throughput to 54 Mbps. In 2009, 802.11n increased the total bandwidth to 150 Mbps using both 5GHz and 2.4GHz bands. The 802.11ac revision (2013) is capable, in theory, of 433 Mbps using wider 80MHz channels in one link using 5GHz. However, in practice, 802.11ac and 802.11n deliver less throughput than these figures. WiFi bandwidth is arranged in 4

separate 20MHz channels per antenna that deliver bandwidths on individual devices of between to 30-90 Mbps (or more, as measured by the author in practice) per 20Mhz link.

The overall bandwidth depends on individual WLAN router or station characteristics such as the number of antennae. Take, for example, each antenna can deliver up to 433 Mbps per 80 Mhz, which is typically split into 4 x 20 MHz channel links. WLAN routers or access points can have up to 8 antennae delivering up to 6.77 Gbit/s. In 2019, WiFi 6 or 802.11ax is designed to operate in bands between 1 and 6 GHz, as they become available. A new revision 802.11ay will operated in the frequency band around 60 GHz, with a theoretical transmission rate of 20–40 Gbs and a transmission distance of 300–500 meters. Thus, WiFi will shortly have the same connectivity as 5G cellular telephony.

All this technical information serves to confuse both lay people and researchers who are not electronic or electrical engineers.[100] Put in simple terms, each 802.11ac access point/router or station/device is like an 8-lane motorway, split into two 4-lane sections where data packets (cars) travel in opposite directions. In the motorway scenario, the amount of traffic in either direction will vary over time, as will the degree of air pollution and noise. It is in the times of heaviest traffic, e.g. in the morning and evening rush hours that traffic, air pollution and noise will be at its maximum. That is when all 4 lanes are busy going in either direction. However, the effects are cumulative. And so it is with the power density (as measured in W/m^2 or V/m) when all 4 links in a router/AP or a single link in each device are transmitting and receiving. This data traffic varies over time as does the related power densities. Hence, the reference to mean and average exposures in research papers cited. This is because data packets from routers/AP and devices are not transmitted continuously. Some researchers assume that the worst-case exposure of WLAN to be 100%, thereby overestimating exposure. This may be the case above with some examples. The actual data transfers or *duty cycles* of a WLAN/router/device are therefore of importance for time-averaging of exposures when assessing the health risks.[101] Some examples will help explain further.

The WiFi power density as measured for a child working 50 cm from a typical laptop was found to be 22,000 $\mu W/m^2$ (peak) in a laboratory study conducted in the UK.[102] Another study found that "Operating with maximal duty factors in a classroom with 30 laptops and an access point at a distance of only 0.5 m could give a maximal personal exposure of 16,600 $\mu W/m^2$".[103] Thus while these peak values are problematic for young children and sensitive people, the following is important to note:

"It is essential to consider the duty cycle—the period during which the Wi-Fi devices are sending. A high-effective Wi-Fi network minimizes the duty cycles, the time the children are exposed and the average exposure value while the students use the Internet, but the background RF radiation may be higher with high peaks and this may influence well-being, especially for electromagnetic hypersensitive persons. … Activated Wi-Fi in mobile phones usually connects very frequently to the Internet (often every 5–10 s)."

Nevertheless, a recent conservative industry-oriented meta-review of studies revealed that the average exposure to WiFi in schools was up to approx. 240 $\mu W/m^2$.[104] Note, again, that the EUROPEAM recommended daytime exposures for normal adults is 10 $\mu W/m^2$ and 3–6 $\mu W/m2$ in the Bioinitiative Report. Following EUROPEAM, the precautionary level children should sensibly be in the range of 1 to 0.1 $\mu W/m^2$. These levels are between 25 to 2500 times lower than that observed in measured exposures in schools. Furthermore, the actual exposures while sitting in front of a device such as an iPad or when also caring a smartphone, are clearly going to be many times higher, somewhere between the average and peak levels reported above. And as Morgan et al.[2] find "Children absorb more [microwave

radiation] than adults because their brain tissues are more absorbent, their skulls are thinner and their relative size is smaller." Thus, there is great uncertainty about the degree of exposure to children and adolescents, and scientifically speaking great risk. The next section places this in a practical context.

Why are the Risks to Children Growing?

The child in the image below is not operating his tablet device safely—that is, he is not in compliance with existing thermal safety standards, insufficient as they may be. As a consequence, his vital organs, central nervous system, eyes and brain are being exposed to unacceptable and potentially unsafe levels of microwave radiation, as calculated above. Over time the cells in his body will develop oxidative stress, due to elevated levels of ROS and attenuated levels of anti-oxidants associated with exposure to microwave radiation. However, the bright light shining on his face is also affecting his developing eyes, which are more sensitive to those of an adult. However, new WiFi technologies operating at 60Ghz, similar to 5G, bring the risk of ocular damage.[105]

What's wrong with this picture?

Vision issues aside, this light acts to significantly attenuate melatonin production in the brain. The first order effect here is interference with the circadian rhythm and sleep disturbance. The research literature on the effect that LED screens have in suppressing melatonin levels is unequivocal. Cajochen et al. provide convincing evidence of the effect that *"A 5-h evening exposure to a white LED backlit screen… elicited a significant suppression of the evening rise in endogenous melatonin and subjective as well as objective sleepiness, as indexed by a reduced incidence of slow eye movements and EEG low-frequency activity (1–7 Hz) in frontal brain regions."*[106] Sleep disruption is also problematic as *"sleep mediates learning and memory processing"* and is vital for memory *"encoding, consolidation, and reconsolidation, into the constellation of additional processes that are critical for efficient memory development."*[107]

However, as melatonin is also one of the body's most effective antioxidants and ROS scavengers[108], it is putting the young child in the image above at particular risk of second-order effects. It specifically increases the probability, that at some point in the future he may develop cancer as an adult. This is dependent on repeated, cumulative exposures to the carcinogen. One must also consider the remote probability that he may develop cancers or other health ill-effects or conditions in childhood.

Cancer aside, scientific experiments have also demonstrated that exposure to WiFi radiation also affects brain development in young rats and their ability to learn and engage in routine problem solving.[109,110,66,67,68,69] The implications for brain development in children are clear, as are the consequences for their immediate well-being.

In considering the above image, this child is probably looking at a YouTube video. He certainly is not reading a school textbook! Children using iPads for school, with texts etc. stored in each device, will start using the device as early as 7 am, in last minute preparations for school and may finish using the device at 8pm, or with older adolescents, much later. That is over 12-14 hours of exposure, much higher than the estimated average of 7 hours of screen time [111]. We know that children watch Youtube or stream content from Netflix etc. which maximizes their exposure to WiFi

RFR. We now that apps on devices remain active and as such many devices do not go into sleep mode and remain on standby if not fully active. We know that children now carry their smartphones, with 4G, Bluetooth and 2.4G and 5G WiFi enabled, on their person. Thus, it seems logical to assume that their exposure to non-thermal effects is higher than it's ever been. It is also logical to conclude that we are be witnessing a health crisis in the making, particularly with 5G now in place.

What do Insurance Companies, Regulators, Telecoms Operators and Lawyers have to say about the Risks?

In 2010 Lloyds of London published a paper on the emerging risks of RFR. [112] At the time it likened links between non-ionizing radiation and cancer to that which exists between asbestos and cancer, indicating that time and more research would establish a causal link. In 2015, rumours spread across the web that Lloyds of London had stopped covering health risks associated with RFR devices. However, it appears that the exclusion of RFR from insurance policies was issued by an individual underwriter, CFC Underwriting Ltd to the effect that: *"The Electromagnetic Fields Exclusion (Exclusion 32) is a General Insurance Exclusion and is applied across the market as standard. The purpose of the exclusion is to exclude cover for illnesses caused by continuous long-term non-ionising radiation exposure, i.e. through mobile phone usage."* It was reported that this exclusion applied to insurance cover for architects and engineers in Canada, following health concerns centering on a programme to install Wi-Fi in all British Columbian schools without parents' consent.

Lloyd's 2010 report predated the IARC's decision in 2011 to classify RFR as a Class 2B carcinogen. As research on the health risks of RFR produces more empirical evidence, insurance companies will act accordingly. Indeed, occupational insurance for medical practitioners now specifically excludes any medical conditions that arise from exposure to non-ionizing radiation such as RFR, including that from phones and mobile devices. Indeed, following this one would expect a strong response from the insurance industry as its actuaries evaluate the risks posed by long-term exposure to RFR in the weight of recent scientific evidence. Thus, in 2019, Swiss Re places 5G as an emerging high risk, with a possible increase in related liability claims[113]. Thus most, if not all, insurance companies will not underwrite coverage for health damages related to RFR exposure from all sources.

Regulators, such as the Securities and Exchange Commission, also recognize the economic impact of risks, as do mobile phone and internet services providers. Take, for example, that Vodafone and Verizon, among others, now include, and make provision for in their financial reports, the risks of litigation in relation to the health effects of products and services involving RFR, whether from smartphones or WiFi routers. Clearly neither believes that the small print in the safety information issued with RFR devices is sufficient. Take, for example, the following excerpt from Vodafone Group PLC, Annual Report.

*"**7. Our business may be impacted by actual or perceived health risks associated with the transmission of radio waves from mobile telephones, transmitters and associated equipment.** Risk: Concerns have been expressed that the electromagnetic signals emitted by mobile telephone handsets and base stations may pose health risks. We are not aware that such health risks have been substantiated, however, in the event of a major scientific finding supporting this view this might result in prohibitive legislation being introduced by governments (or the European Union), a major reduction in mobile phone usage (especially by children), a requirement to move base station sites, significant difficulty renewing or acquiring site leases, and/or major litigation. An inadequate response to electromagnetic fields ('EMF') issues may result in loss of confidence in the industry and Vodafone."*[114]

The advent of 5G technologies has brought the legal profession into the arena. In a comprehensive legal opinion by Danish lawyer Christian F. Jensen, he concludes:

"It is the conclusion of this legal opinion that establishing and activating a 5G-network, as it is currently described, would be in contravention of current human and environmental laws enshrined in the European Convention on Human Rights, the UN Convention on the Rights of the Child, EU regulations, and the Bern- and Bonn-conventions.

The reason is the very significant body of scientific documentation available, showing that radiofrequency electromagnetic radiation is harmful and dangerous to the health of humans (particularly children), animals and plants."

Also, Australian barrister Ray Broomhall is setting legal precedence in Australia in challenging 5G roll-out and protecting electrosensitive people from wireless radiation.[115]

Conclusions

In a submission to the United Nations in 2015, over 200 scientists requested that it address *"the emerging public health crisis"* related to the use of RFR emitting devices.[116] They urged the United Nations Environmental Programme (UNEP) to review current exposure standards and to identify measures to substantially lower human exposures to microwave radiation. The scientists argued that existing *"guidelines do not cover long-term exposure and low-intensity effects"* and are *"insufficient to protect public health."* They note the urgency in this, as children are more vulnerable to the effects of RFR.

Microwave radiation is considered by majority of independent scientists as an invisible source of potentially toxic pollution that scientific research across the sciences has identified as being harmful to biological systems and, ultimately, human health and well-being. Think of a smoke-filled bar of yore, where smokers and non-smokers alike are subjected to toxic carcinogens. Now, think of that same bar in countries where smoking is banned from such premises. However, have we replaced one hazard with another, if one considers the RFR being emitted by the WiFi routers/access points, and radio units all of the smart devices in pubs, cafes, restaurants, homes, schools, and the workplace. In the age of the Internet of Things (IoT), the scale of the dilemma that we have unthinkingly drifted into becomes clear. That, is of course, if one accepts the scientific evidence.

All this is of concern to computer scientists and technologists, who find the exposure to a multiplicity of, and close proximity to, WiFi and other RFR signals problematic. Take, for example, Ajay Malik, SVP of Engineering and Products, Network World, who has also called for the WiFi standard to be reviewed by the FCC. He argues that the *"amount of radiation exposure today is over 100 times higher as we live in proximity to a very large number of actively transmitting Wi-Fi Devices and Wi-Fi Access Points/Routers."* [117] He therefore raises questions on the cumulative impact on adults and children of these unplanned for levels of exposure that often can go beyond SAR safety limits. Of course, he is unaware of the non-thermal health effects which are, perhaps, of greater concern, as the relevant mechanisms operate at lower exposure levels and shorter durations.

As far back as 1973, a review and study by Russian scientists on the effects of low-intensity RFR on experimental animals indicated clear evidence of effects on the brain and nervous system, and also the heart and testes, of subjects.[118] Historically, Russia has more stringent safety standards than the West, whether it is the EU or US, when it comes to RFR.[91] This was first identified by naval researchers in their review of Soviet and Eastern-Bloc studies, initially at a symposium in 1969.[5] By 1976, the US Naval Medical Research Institute (NMRI) had published a bibliography of 3,700 scientific papers on the thermal and non-thermal biological effects of RFR, when the last of a series of supplements to the original report in 1972 were integrated (see Glaser, Brown and Brown, 1976 [7]). In

summary, the NMRI identified the following findings:

- Thermal effects identified include heating of the whole body, brain, eyes, testicles, and sinuses, among others.
- Non-thermal effects identified include oxidative process change (a precursor for DNA strand breaks and ultimately cancer), decreased fertility, altered fetal development, muscle contraction, cardiovascular changes, altered menstrual activity, liver enlargement, changes in conditioned reflexes, and so on. [119]

The evidence provided by Russian scientists and their contemporaries in the US and Europe should have given pause to the telecommunications industry and regulators in relation to the commericalisation and widespread use of mobile telephony in the 1980s. However, in 2019 the cumulative body of scientific evidence should have governments and regulators take immediate action to change policy and implement appropriate safety standards for digital technologies, as it is children that are most at risk.

Concern has increased about such risks as in March 2019, based on recent laboratory and epidemiological evidence, an Advisory Group of 29 scientists from 18 countries recommended that non-ionizing RFR be prioritized by the WHO's International Agency for Research on Cancer (IARC) Monographs programme during 2020–24. They are concerned about the health risks identified by research over the past 8 years. So are the majority of independent researchers as they have called for non-ionizing microwave radiation to be reclassified as a Class 1 carcinogen, along with cigarette smoke. [120] Furthermore, over 250 scientists and professionals in biophysics, medicine, health, and related fields have requested the United Nations to introduce a moratorium on 5G, given the related health risks for humans and threat to the environment.[121]

Some governments recognize the risk and are taking action. Take, for example, that the state of Oregon passed SB 283 in June 2019. This is a "bill relating to exposure to radiation in schools in this state; and declaring an emergency." The radiation

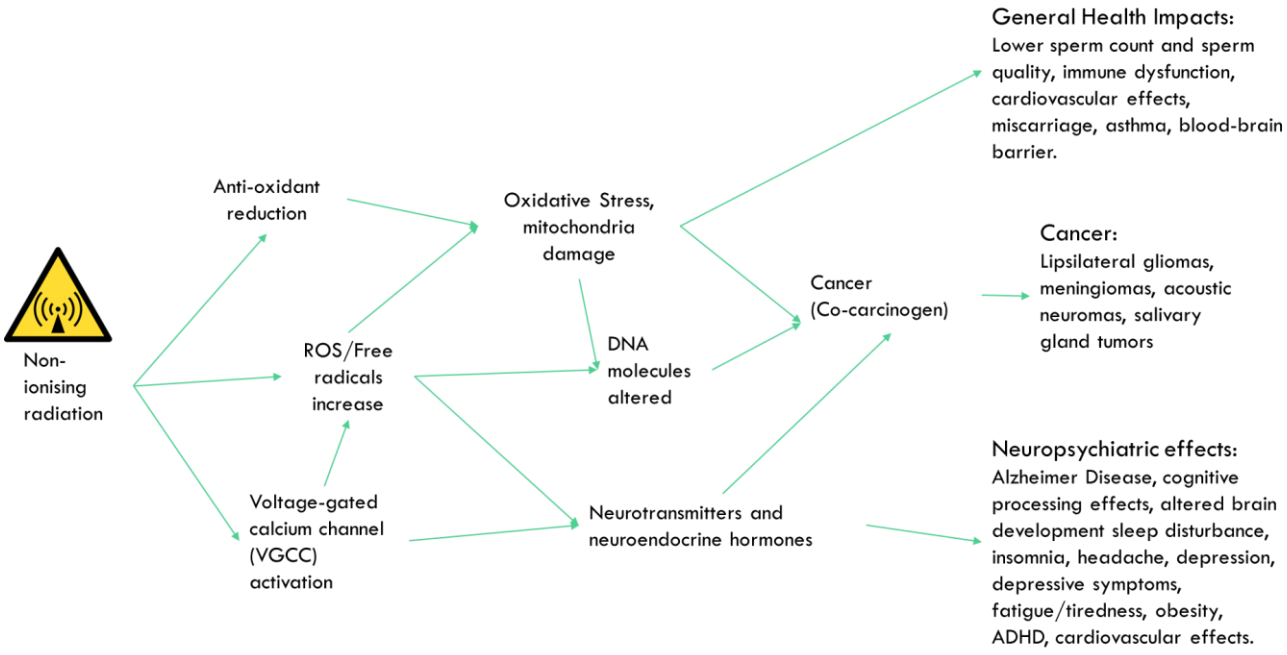

General Health Impacts:
Lower sperm count and sperm quality, immune dysfunction, cardiovascular effects, miscarriage, asthma, blood-brain barrier.
Anti-oxidant reduction
Oxidative Stress, mitochondria damage
Cancer:
Lipsilateral gliomas, meningiomas, acoustic neuromas, salivary gland tumors
Cancer (Co-carcinogen)
Non-ionising radiation
ROS/Free radicals increase
DNA molecules altered
Neuropsychiatric effects:
Alzheimer Disease, cognitive processing effects, altered brain development sleep disturbance, insomnia, headache, depression, depressive symptoms, fatigue/tiredness, obesity, ADHD, cardiovascular effects.
Voltage-gated calcium channel (VGCC) activation
Neurotransmitters and neuroendocrine hormones

Figure 3 RFR Mechanisms and Outcomes

here is WiFi microwave radiofrequency radiation, which, as indicated was declared a Class 2B carcinogen by the World Health Organisation's IARC in 2011. The weight of scientific evidence prompted Oregon's politicians to vote 50-8 for the measure. Inter alia, the Bill obliges "the Oregon Department of Education to develop recommendations to schools in this state for practices and alternative technologies that reduce students' exposure to microwave radiation that Oregon Health Authority report identifies as harmful."

Given the clear risks that RFR-based technologies present, it is also vital for parents and educators to take immediate action on the use of microwave emitting devices where children are concerned. As there is overwhelming evidence that safety standards are woefully outdated, the action to be taken is clear. The *precautionary principle* should be applied and the use of all microwave RFR-enabled devices, from WiFi-enabled tablets (and smartphones) to WiFi routers, should be heavily curtailed or eliminated. Figure 2 summarizes this paper's findings and provides compelling reasons for why such action is necessary.

As indicated, Figure 2 summarises the evidence of risk and indicates the role of specific mechanisms in producing the various threats to human health and well-being. Each of the outcomes identified are independent of each other; hence, the risk of some form of ill-health to children due to RFR exposure is highly probable. If we take cancers, evidence presented above indicates that the incidence and the prevalence of frontal and temporal lobe brain tumours has increased with statistical significance. Children are particularly vulnerable and their risk exposure extremely high.

At the risk of repetition, there is only one realistic course of action. Children and adolescents should not be using smartphones or WiFi-enabled tablet devices, and their expose to RFR sources should be minimized. This might seem impractical in the digital world, but in our real analogue world, children and teenagers are no longer permitted legal access to cigarettes, nor is it socially acceptable for adults to smoke in their presence. Given the current scientific evidence, the pathophysiological properties of RFR appear to be no different than cigarette smoke or similar carcinogens.

Thus, in light of the evidence, the *precautionary principle* should be applied and governments should implement policies that result in the removal of WiFi routers and all WiFi devices from the classrooms of elementary/primary and secondary/high schools. Just to remind the reader what the *precautionary principle* means: *"When an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically."* [122] We are well beyond that point, as this paper illustrates. The application of the *precautionary principle* is a statutory requirement in some areas of law in the European Union, as expressed in the *Charter of Fundamental Rights*. Thus EU governments at least have a political and an ethical responsibility to act.

In the absence of appropriate government policy, educators need to reconsider the untrammeled use of WiFi in schools and not employ iPads or tablets for use by children in class. Devices that use e-Ink, or similar types of electronic paper display, as opposed to LED screens, should be used in the classroom and at home to access e-books/texts, but these should be operated in airplane mode when reading.

Parents and guardians also need to act and should consider the following recommendations in order to exercise their personal duty of care:

- Educate children and adolescents about the health risks of RFR.
- Restrict device time to a maximum 30 minutes for all RFR-enabled devices, not just screen time.
- In respect of screen time, all LED screen devices should have a Blue

Light Filter. Apps like F-Lux are ideal here. This minimises melatonin reduction in users.

- Smart phones have 2/3/4G, WiFi and Bluetooth radio units all of which are normally switched on. These should be used only when required. In addition, the small print on Health and Safety information that comes with a smartphone typically indicates that they should NOT be carried nor operated less than 2.5 cm from the body.
- Remember that the WiFi Safety standards for ALL devices is that they must be operated 20 cm or 8" from the body and for no more than 30 minutes.
- Given the RFR risk, handing a young child an active RFR device, such as a smartphone or an iPad, to hold in their car seat/pram, is for all intents and purposes the same as giving them a cigarette to smoke.
- If children or adolescents have access to smartphones and WiFi devices, the devices should not be carried or operated on or near their person.
    - Wired ear buds & microphone sets should be used for all calls.
- If children are using a screen device for games, they should be operated in airplane mode.
- Ensure WiFi routers are not in or near or directly beneath children's bedrooms and they should be switched off at night. No RFR device, including some types of baby monitors, should in in a child's bedroom.
- Minimise the use in the home of all Internet of Things (IoT) devices such as Smart Meters, Virtual Assistants, Hive, Chromecast, WiFi dongles, and so on.

There is also a clear onus on scientists and practitioners in the computing and IT industry to act and ensure that the safety standards for all RFR and WiFi devices are reviewed in light of the recent scientific findings. To do otherwise would be irresponsible and unethical. There will be enormous resistance to change from vested interests and the political establishment. This has already happened, with orchestrated campaigns against natural scientists conducting independent research on the health implications of RFR, particularly in the US.[123]

An excerpt from a recent article in *The Guardian* newspaper summarises the type of response to be expected from industry with respect to microwave RFR and in particular the release of the findings of the NTP study. *"Central to keeping the scientific argument going is making it appear that not all scientists agree. Towards that end, and again like the tobacco and fossil-fuel industries, the wireless industry has "war-gamed" science, as a Motorola internal memo in 1994 phrased it. War-gaming science involves playing offence as well as defence – funding studies friendly to the industry while attacking studies that raise questions; placing industry-friendly experts on advisory bodies such as the World Health Organisation and seeking to discredit scientists whose views differ from the industry's."* [124]

Returning to the quote at the beginning of this paper by Professor Frentzel-Beyme MD, we have, as the evidence adduced herein indicates, far exceeded the *"level of proof required to justify action for health protection."* The theory that non-ionizing RFR exposure could ***not*** cause cancer has been refuted using the scientific method. It is ironic, in the era of neoconservatism, neoliberalism, and the anti-environmental policies in the U.S., that the smoking gun should be provided by the National Toxicology Program of the U.S. Department of Health and Human Services. This study, as indicated above, is just the latest of

many to provide the "*clear evidence"* required for policy and social change.

The need for social change is this area is as important, and no less controversial, than that required to respond to the challenge of global warming. However, the forces resisting change to the *status quo* are equally considerable. Take for example that *"Not one major news organisation in the US or Europe reported [the] scientific news [published by the NTP]. But then, news coverage of mobile phone safety has long reflected the outlook of the wireless industry."*[53]

The Last Word belongs to the Philosophy of Science

This paper's penultimate word goes to preeminent Philosopher of Science and champion of the scientific method, Sir Karl Popper. In the *The Open Society,* Popper states, "[i]f we wish freedom to be safeguarded, then we must demand that the policy of unlimited economic freedom be replaced by the planned economic intervention of the state. We must demand that unrestrained capitalism give way to economic interventionism." The economic freedom and self-regulation accorded to technology firms should be balanced with the need to protect the interests, health and well-being of the citizenry. This was recently underlined in another context by Professor Shoshana Zuboff, who critiques the activities of BigTech firms and the consequences for individuals and society.[125] Likewise, Professor Sherry Turkle, paints an equally grim picture of the impact of digital technology on our general well-being. [126] However, neither were aware of, nor address, the fundamental way in which the same technologies create fundamental risks for human health and well-being. Equally unaware and misinformed are politicians and policy makers, whether in nation states and wider communities such as the EU.

It must be remembered that the introduction of wireless digital technologies happened in a piecemeal fashion. There was no cost-benefit analysis, in terms of the obvious benefits of enhanced communication and information access and exchange, versus the unintended consequences and risks. Driven by '*technological fundamentalism,'* and the general belief that digital technology is neutral and therefore carries no unintended consequences or risks, politicians, policy makers, and society were misled by the telecommunications industry in the U.S. and Europe into believing that wireless technologies are safe.

What should have happened, post-1976, when the risks were indicated by the U.S. Naval Medical Research Institute, is that governments should have followed Popper's general advice viz. limited the scope of technological change in line with independent scientific research on thermal and non-thermal risks, which predicted the outcomes for individuals and society.

Professor Nassim Taleb, extended Popper's perspective, by identifying the consequences of ignoring black swan risk.[127] In a subsequent tome, he correctly argues that "[o]ur record of understanding risks in complex systems (biology, economics, climate) has been pitiful, marred with retrospective distortions (we only understand the risks after the damage takes place, yet we keep making the mistake), and there is nothing to convince me that we have gotten better at risk management." [128] The truth of the risks posed by RFR—4G, 5G and WiFi—is there for all to see. But it's not that simple to access or understand.

Popper indicates in his masterwork, *Conjectures and Refutations*, that scientific truth is difficult to achieve, particularly as people tend to be "good, but stupid" and easily "led by the nose".[21] His theory explains why we are in the mess we currently find ourselves, not only concerning wireless digital technologies, but a raft of other environmental risks.

One of the greatest environmental disasters of recent times was the accident involving ionizing radiation at Chernobyl. In the HBO docudrama the following is attributed to the scientist responsible for averting a global catastrophe, Dr. Valery Legasov:

"To be a scientist is to be naive. We are so focused on our search for truth we fail to consider how few actually want us to find it. But it is always there whether we see it or not, whether we choose to or not. The truth doesn't care about our needs or wants—it doesn't care about our governments, our ideologies, our religions—it will lie in wait for all time…Where I once would fear the cost of truth, now I only ask what is the cost of lies."

I am a scientist, and equally naïve, and equally fallible, as any other human. However, no matter how difficult, how elusive, how controversial, how personally costly, my quest for the truth is unswerving. Nevertheless, as Popper holds, the truth is hard to come by, particularly in the digital age, as fake news and personal opinion dominates over scientific fact.

In order to combat vested interests and protect children, parents and grandparents, aunts and uncles, need to inform themselves, to act and change extant social perspectives on seemingly harmless digital technologies that entertain and beguile, and which offer affordances without apparent consequences. That will be the challenge for readers of this paper. To understand that technology is not neutral—that it has negative as well as positive consequences for users and society, and that there is a dark side to the bright screen on which you may be reading this article.

About the Author

Professor Tom Butler is a social scientist at University College Cork. A former satellite and microwave communications specialist and an IT professional, he is more than familiar with the traditional safety issues relating to microwave RFR. His *Pauline conversion* from the engineering perspective on RFR thermal safety occurred through research engagements with the Chief Risk Officer of a global corporation who pointed out the significant risks to children from the non-thermal effects of RFR. These discussions and related events in his personal life stimulated Professor Butler's interest in this important topic.

In a research context, Tom is a former Government of Ireland Research Fellow, Principal Investigator (PI) of the Governance Risk and Compliance Technology Centre (2013-2018), PI of the SmaRT and SamRT4Reg Commercialisation Fund Projects (2017-2019), and Co-PI of two Marie Skłodowska-Curie Career-FIT Fellowships in Artificial Intelligence (2019-2022). With over €8.5 million in research funding on the application of digital technologies to date, he has over 220 publications and 11 inventions. Tom is a member of the European Commission's Expert Group on Regulatory Obstacles to Financial Innovation (ROFIEG) in the area of FinTech.

References

[1] Belpomme, D., Hardell, L., Belyaev, I., Burgio, E., & Carpenter, D. O. (2018). Thermal and non-thermal health effects of low intensity non-ionizing radiation: An international perspective. Environmental pollution, 242, 643-658.

[2] Morgan, L. L., Kesari, S., & Davis, D. L. (2014). Why children absorb more microwave radiation than adults: The consequences. Journal of Microscopy and Ultrastructure, 2(4), 197-204.

[3] Guideline, ICNIRP (1998). Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz). Health phys, 74(4), 494-522.

[4] Cherry, N. J. (2002). Criticism of the health assessment in the ICNIRP guidelines for radiofrequency and microwave radiation (100 kHz-300 GHz). Invited submission to the Ministry of Health/ Ministry for the Environment of New Zealand on the adoption of the ICNIRP guidelines.

[5] Dodge, C. H. (1969, September). Clinical and hygienic aspects of exposure to electromagnetic fields: A review of Soviet and East European literature. In Biological Effects and health Implications of Microwave Radiation Symposium Proceedings, SF Cleary, ed., BRH, DBE Report (pp. 70-2).

[6] https://ehtrust.org/wp-content/uploads/Naval-MRI-Glaser-Report-1976.pdf

[7] Glaser, Z. (1972). Bibliography of reported biological phenomena ("effects") and clinical manifestations attributed to microwave and radio-frequency radiation. Naval Medical Research Institute – National Naval Medical Center, Bethesda, USA.

[8] Attributed to S. J. Green BAT, https://www.who.int/tobacco/media/en/TobaccoExplained.pdf

[9] Huss, A., Egger, M., Hug, K., Huwiler-Müntener, K., & Röösli, M. (2006). Source of funding and results of studies of health effects of mobile phone use: systematic review of experimental studies. Environmental health perspectives, 115(1), 1-4.

[10] https://bioinitiative.org/research-summaries/

[11] Goldacre, B. (2014). Bad pharma: how drug companies mislead doctors and harm patients. Macmillan.

[12] See https://ehtrust.org/policy/phonegate-cell-phone-radiation-exceeds-limits-tested-body-contact-position/

[13] https://www.chicagotribune.com/investigations/ct-cell-phone-radiation-testing-20190821-72qgu4nzlfda5kyuhteiieh4da-story.html

[14] Alster, N. (2015). Captured agency: How the Federal Communications Commission is dominated by the industries it presumably regulates. Edmond J. Safra Center for Ethics, Harvard University.

[15] https://www.thenation.com/article/how-big-wireless-made-us-think-that-cell-phones-are-safe-a-special-investigation/

[16] https://today.law.harvard.edu/at-center-for-ethics-event-cell-phone-radiation-and-institutional-corruption-addressed-video/

[17] https://www.emfscientist.org/index.php/emf-scientist-appeal

[18] Kuhn, T. S. (2012). The structure of scientific revolutions. University of Chicago press.

[19] Pockett, S. (2019). Conflicts of Interest and Misleading Statements in Official Reports about the Health Consequences of Radiofrequency Radiation and Some New Measurements of Exposure Levels. Magnetochemistry, 5(2), 31.

[20] Popper, K. (2005). The logic of scientific discovery. Routledge.

[21] Popper, K. (2014). Conjectures and refutations: The growth of scientific knowledge. Routledge.

[22] David, L. (1980). Study of federal microwave standards (No. DOE/ER/10041-02). PRC Energy Analysis Co., McLean, VA (USA).

[23] EPA (1984). Biological Effects of Microwave Radiation, Environmental Protection Agency, Final Report, September 1984.

[24] General Accounting Office (2001) Telecommunications, Research and Regulatory Efforts on Mobile Phone Health https://books.google.ie/books?id=K992xTuMOlwC&pg=PA27&lpg=PA27&dq=FDA+Consumer+Update+on+Mobile+Phones+1999&source=bl&ots=Xw2OcOPHcs&sig=ACfU3U0pJFCBYvIWEgh7rxVBi-v-5ytp-w&hl=en&sa=X&ved=2ahUKEwihy-GU347lAhX_RBUIHdi7DXoQ6AEwCXoECAcQAQ

[25] Carlo, G. L., & Schram, M. (2001). Cell Phones: Invisible Hazards in the Wireless Age: an Insider's Alarming Discoveries about Cancer and Genetic Damage. Carroll & Graf.

[26] Alster, N. (2015). Captured agency: How the Federal Communications Commission is dominated by the industries it presumably regulates. Harvard University: Cambridge, MA, USA.

[27] Melnick, R. L. (2019). Commentary on the utility of the National Toxicology Program Study on cell phone radiofrequency radiation data for assessing human health risks despite unfounded criticisms aimed at minimizing the findings of adverse health effects. Environmental research, 168, 1-6.

[28] Hardell, L., & Carlberg, M. (2019). Comments on the US National Toxicology Program technical reports on toxicology and carcinogenesis study in rats exposed to whole-body radiofrequency radiation at 900 MHz and in mice exposed to whole-body radiofrequency radiation at 1,900 MHz. International journal of oncology, 54(1), 111-127.

[29] Kuhn, T. S. (1962). The structure of scientific revolutions. Chicago and London.

[30] Food and Drug Administration (FDA) (1999). Nomination Letter to Coordinator of NTP Chemical Nomination and Selection Committee. nomihttps://ntp.niehs.nih.gov/ ntp/htdocs/chem_background/exsumpdf/wireless051999_508.pdf .

[31] Vijayalaxmi & Obe, G., (2004). Controversial cytogenetic observations in mammalian somatic cellsexposed to radiofrequency radiation, Radiat. Res. 162 (5), 481–96.

[32] National Toxicology Programme (2018a). Cell Phone Radio Frequency Radiation Studies. https://www.niehs.nih.gov/health/materials/cell_phone_radiofrequency_radiation_studies_508.pdf.

[33] National Toxicology Programme (2018b). Cell Phone Radio Frequency Radiation. https://ntp.niehs.nih.gov/results/areas/cellphones/index.html?utm_source=direct&utm_medium=prod&utm_campaign=ntpgolinks&utm_term=cellphone

[34] Morgan, L. L., Miller, A. B., Sasco, A., & Davis, D. L. (2015). Mobile phone radiation causes brain tumors and should be classified as a probable human carcinogen (2A). International journal of oncology, 46(5), 1865-1871.

[35] National Toxicology Programme (2018c). High Exposure to Radio Frequency Radiation Associated With Cancer in Male Rats, Telephone Press Conference, 10/31/18, 2:00 pm ET. https://www.nih.gov/news-events/news-releases/high-exposure-radio-frequency-radiation-associated-cancer-male-rats.

[36] Wyde, M. (2016). NTP toxicology and carcinogenicity studies of cell phone radiofrequency radiation. BioEM2016 Meeting, Ghent, Belgium. https://ntp.niehs.nih.gov/ntp/research/areas/cellphone/slides_bioem_wyde.pdf .

[37] https://www.ramazzini.org/comunicato/onde-elettromagnetiche-listituto-ramazzini-risponde-allicnirp/

[38] Falcioni, L., Bua, L., Tibaldi, E., Lauriola, M., De Angelis, L., Gnudi, F., Mandrioli, D., Manservigi, M., Manservisi, F., Manzoli, I. & Menghetti, I. (2018). Report of final results regarding brain and heart tumors in Sprague-Dawley rats exposed from prenatal life until natural death to mobile phone radiofrequency field representative of a 1.8 GHz GSM base station environmental emission. Environmental research, 165, 496-503.

[39] http://ehtrust.org/the-california-medical-association-wireless-resolution/

[40] https://ecfsapi.fcc.gov/file/7520941318.pdf

[41] https://www.nytimes.com/2018/11/01/health/ cellphone-radiation-cancer.html

[42] Mialon, H. M., & Nesson, E. T. (2018). Mobile Phones and the Risk of Brain Cancer Mortality: A Twenty-Five Year Cross-Country Analysis. (February 26, 2017). Available at SSRN: https://ssrn.com/abstract=2674296 or http://dx.doi.org/10.2139/ssrn.2674296.

[43] Coureau, G., Bouvier, G., Lebailly, P., Fabbro-Peray, P., Gruber, A., Leffondre, K., ... & Baldi, I. (2014). Mobile phone use and brain tumours in the CERENAT case-control study. Occup Environ Med, oemed-2013.

[44] Philips, A.. Henshaw, D., L Lamburn, G. & M. O'Carroll, (2018). Brain tumours: rise in Glioblastoma Multiforme incidence in England 1995–2015 suggests an adverse environmental or lifestyle factor, Journal of Environmental and Public Health, vol. 2018, Article ID 7910754.

[45] Ostrom, Q. T., Gittleman, H., Xu, J., Kromer, C., Wolinsky, Y., Kruchko, C., & Barnholtz-Sloan, J. S. (2016). CBTRUS statistical report: primary brain and other central nervous system tumors diagnosed in the United States in 2009–2013. Neuro-oncology, 18(suppl_5), v1-v75.

[46] Khanna, V., Achey, R. L., Ostrom, Q. T., Block-Beach, H., Kruchko, C., Barnholtz-Sloan, J. S., & de Blank, P. M. (2017). Incidence and survival trends for medulloblastomas in the United States from 2001 to 2013. Journal of neuro-oncology, 135(3), 433-441.

[47] Withrow, D. R., de Gonzalez, A. B., Lam, C. J., Warren, K. E., & Shiels, M. S. (2018). Trends in pediatric central nervous system tumor incidence in the United States, 1998-2013. Cancer Epidemiology and Prevention Biomarkers, cebp-0784.

[48] Röösli, M., Lagorio, S., Schoemaker, M. J., Schüz, J., & Feychting, M. (2019). Brain and Salivary Gland Tumors and Mobile Phone Use: Evaluating the Evidence from Various Epidemiological Study Designs. Annual review of public health, 40.

[49] West, J. G., Kapoor, N. S., Liao, S. Y., Chen, J. W., Bailey, L., & Nagourney, R. A. (2013). Multifocal breast cancer in young women with prolonged contact between their breasts and their cellular phones. Case reports in medicine, 2013.

[50] Hardell, L., & Carlberg, M. (2015a). Increasing rates of brain tumours in the Swedish national inpatient register and the causes of death register. International journal of environmental research and public health, 12(4), 3793-3813.
Hardell, L., & Carlberg, M. (2015b). Mobile phone and cordless phone use and the risk for glioma–Analysis of pooled case-control studies in Sweden, 1997–2003 and 2007–2009. Pathophysiology, 22(1), 1-13.
Hardell, L., & Carlberg, M. (2017). Mobile phones, cordless phones and rates of brain tumors in different age groups in the Swedish National Inpatient Register and the Swedish Cancer Register during 1998-2015. PloS one, 12(10), e0185461

[51] Swedish Radiation Protection Foundation (2017). Brain tumors are increasing in Denmark https://www.stralskyddsstiftelsen.se/wp-content/uploads/2017/01/denmark_cnstumorsrising_2017-01-20.pdf

[52] Patel, A. P., Fisher, J. L., Nichols, E., Abd-Allah, F., Abdela, J., Abdelalim, A., ... & Allen, C. A. (2019). Global, regional, and national burden of brain and other CNS cancer, 1990–2016: a systematic analysis for the Global Burden of Disease Study 2016. The Lancet Neurology, 18(4), 376-393.

[53] http://aspho.org/uploads/meetings/2018annualmeeting/Abstracts_for_Website.pdf

[54] Ostrom, Q. T., Gittleman, H., Truitt, G., Boscia, A., Kruchko, C., & Barnholtz-Sloan, J. S. (2018). CBTRUS statistical report: primary brain and other central nervous system tumors diagnosed in the United States in 2011–2015. Neuro-oncology, 20(suppl_4), iv1-iv86.

[55] Virostko, J., Capasso, A., Yankeelov, T. E., & Goodgame, B. (2019). Recent trends in the age at diagnosis of colorectal cancer in the US National Cancer Data Base, 2004-2015. Cancer.

[56] Araghi, M., Soerjomataram, I., Bardot, A., Ferlay, J., Cabasag, C. J., Morrison, D. S., ... & Engholm, G. (2019). Changes in colorectal cancer incidence in seven high-income countries: a population-based study. The Lancet Gastroenterology & Hepatology, 4(7), 511-518.

[57] Vuik, F. E., Nieuwenburg, S. A., Bardou, M., Lansdorp-Vogelaar, I., Dinis-Ribeiro, M., Bento, M. J., ... & Suchanek, S. (2019). Increasing incidence of colorectal cancer in young adults in Europe over the last 25 years. Gut, gutjnl-2018.

[58] Chauhan, P., Verma, H. N., Sisodia, R., & Kesari, K. K. (2017). Microwave radiation (2.45 GHz)-induced oxidative stress: Whole-body exposure effect on histopathology of Wistar rats. Electromagnetic Biology and Medicine, 36(1), 20-30.

[59] Carpenter, D. O., & Bushkin-Bedient, S. (2013). Exposure to chemicals and radiation during childhood and risk for cancer later in life. Journal of Adolescent Health, 52(5), S21-S29.

[60] Christ, Andreas, Marie-Christine Gosselin, Maria Christopoulou, Sven Kühn, & Niels Kuster. (2010). Age-dependent tissue-specific exposure of cell phone users. *Physics in medicine and biology*, 55(7): 1767.

[61] Keshvari, J., Keshvari, R., & Lang, S. (2006). The effect of increase in dielectric values on specific absorption rate (SAR) in eye and head tissues following 900, 1800 and 2450 MHz radio frequency (RF) exposure. *Physics in Medicine and Biology*, *51*(6), 1463.

[62] Gandhi, O. P., Morgan, L. L., de Salles, A. A., Han, Y. Y., Herberman, R. B., & Davis, D. L. (2012). Exposure limits: the underestimation of absorbed cell phone radiation, especially in children. Electromagnetic Biology and Medicine, 31(1), 34-51

[63] Li, D. K., Chen, H., Ferber, J. R., Odouli, R., & Quesenberry, C. (2017). Exposure to magnetic field non-ionizing radiation and the risk of Miscarriage: A prospective cohort study. Scientific reports, 7(1), 17541.

[64] Li, D. K., Chen, H. & Odouli, R. (2011). Maternal Exposure to Magnetic Fields During Pregnancy in Relation to the Risk of Asthma in Offspring. Arch.Pediatr.Adolesc.Med.

[65] Li, D. K., Ferber, J. R., Odouli, R. & Quesenberry, C. P. Jr. (2012). A prospective study of in-utero exposure to magnetic felds and the risk of childhood obesity. Sci.Rep. 2, 540.

[66] Aldad, T. S., Gan, G., Gao, X. B., & Taylor, H. S. (2012). Fetal radiofrequency radiation exposure from 800-1900 mhz-rated cellular telephones affects neurodevelopment and behavior in mice. Scientific reports, 2, 312.

[67] Othman, H., Ammari, M., Rtibi, K., Bensaid, N., Sakly, M., Abdelmelek, H. (2017). Postnatal development and behavior effects of in-utero exposure of rats to radiofrequency waves emitted from conventional WiFi devices. Environ. Toxicol. Pharmacol. 52:239-247. doi: 0.1016/j.etap.2017.04.016.

[68] Kumari K, Koivisto H, Myles C, Jonne N, Matti V, Heikki T, Jukka J. (2017). Behavioural phenotypes in mice after prenatal and early postnatal exposure to intermediate frequency magnetic fields. Environ Res 162: 27-34

[69] Othman, H., Ammari, M., Sakly, M., & Abdelmelek, H. (2017). Effects of prenatal exposure to WIFI signal (2.45 GHz) on postnatal development and behavior in rat: influence of maternal restraint. Behavioural brain research, 326, 291-302.

[70] Divan HA, Kheifets L, Obel C, Olsen J. (2008). Prenatal and postnatal exposure to cell phone use and behavioral problems in children. Epidemiology 19:523-529. doi: 10.1097/EDE.0b013e318175dd47.
[71] Divan HA, Kheifets L, Obel C, Olsen J. (2012). Cell phone use and behavioural problems in young children. J Epidemiol Community Health. 2012 Jun;66(6):524-9. doi: 10.1136/jech.2010.115402.
[72] Frentzel-Beyme, R. (1994). John R. Goldsmith on the usefulness of epidemiological data to identify links between point sources of radiation and disease. Public health reviews, 22(3-4), 305-320.
[73] Waris G, Ahsan H. (2016). Reactive oxygen species: role in the development of cancer and various chronic conditions. Journal of Carcinogenesis. 2006;5(14). doi:10.1186/1477-3163-5-14.
[74] De Iuliis, G. N., Newey, R. J., King, B. V., & Aitken, R. J. (2009). Mobile phone radiation induces reactive oxygen species production and DNA damage in human spermatozoa in vitro. PloS one, 4(7), e6446.
[75] Yakymenko, I., Tsybulin, O., Sidorik, E., Henshel, D., Kyrylenko, O., & Kyrylenko, S. (2016). Oxidative mechanisms of biological activity of low-intensity radiofrequency radiation. Electromagnetic biology and medicine, 35(2), 186-202.
[76] Nazıroğlu, M., Yüksel, M., Köse, S. A., & Özkaya, M. O. (2013). Recent reports of Wi-Fi and mobile phone-induced radiation on oxidative stress and reproductive signaling pathways in females and males. The Journal of membrane biology, 246(12), 869-875.
[77] Pall, M. L. (2018). Wi-Fi is an important threat to human health. Environmental research, 164, 405-416.
[78] Pall, M.L., (2013). Electromagnetic fields act via activation of voltage-gated calcium channels to produce beneficial or adverse effects. J. Cell. Mol. Med. (17), 958–965. http://dx.doi.org/10.1111/jcmm.12088.
[79] Kesari, K. K., Siddiqui, M. H., Meena, R., Verma, H. N., & Kumar, S. (2013). Cell phone radiation exposure on brain and associated biological systems. Indian Journal of Experimental Biology, March 2013; 51: 187–200.
[80] Han, Y. Y., Gandhi, O. P., De Salles, A., Herberman, R. B., & Davis, D. L. (2010). Comparative assessment of models of electromagnetic absorption of the head for children and adults indicates the need for policy changes. Eur J Oncol. Volume, 5, 301-318.
[81] Kheifets, L., Repacholi, M., Saunders, R., & Van Deventer, E. (2005). The sensitivity of children to electromagnetic fields. Pediatrics, 116(2), e303-e313.
[82] Akhavan-Sigari, R., Baf, M. M. F., Ariabod, V., Rohde, V., & Rahighi, S. (2014). Connection between cell phone use, p53 gene expression in different zones of glioblastoma multiforme and survival prognoses. Rare Tumors, 6(3).
[83] Hardell, L., & Carlberg, M. (2015a). Increasing rates of brain tumours in the Swedish national inpatient register and the causes of death register. International journal of environmental research and public health, 12(4), 3793-3813.
[84] Hardell, L., & Carlberg, M. (2015b). Mobile phone and cordless phone use and the risk for glioma–Analysis of pooled case-control studies in Sweden, 1997–2003 and 2007–2009. Pathophysiology, 22(1), 1-13.
[85] Carlberg, M., Hedendahl, L., Ahonen, M., Koppel, T., & Hardell, L. (2016). Increasing incidence of thyroid cancer in the Nordic countries with main focus on Swedish data. BMC cancer, 16(1), 426.
[86] Portier, C.J., & Leonard W.L. (2016). Do Cell Phones Cause Cancer? Probably, but It's Complicated, Scientific American, June 13, 2016.
[87] Tillmann, T., Ernst, H., Streckert, J., Zhou, Y., Taugner, F., Hansen, V., Dasenbrock, C., (2010). Indication of cocarcinogenic potential of chronic UMTS-modulated radiofrequency exposure in an ethylnitrosourea mouse model. Int. J. Radiat. Biol. 86, 529–541.
[88] Lerchl, A., Klose, M., Grote, K., Wilhelm, A. F., Spathmann, O., Fiedler, T., ... & Clemens, M. (2015). Tumor promotion by exposure to radiofrequency electromagnetic fields below exposure limits for humans. Biochemical and biophysical research communications, 459(4), 585-590.
[89] Swankin and Turner (2016). See at https://ehtrust.org/wp-content/uploads/Swankin-Turner-Letter-to-FCC-w-signature.pdf
[90] Phonegate. https://ehtrust.org/cell-phone-radiation-scandal-french-government-data-indicates-cell-phones-exposeconsumers-radiation-levels-higher-manufacturers-claim/
[91] Grigoriev Y. (2017). Methodology of Standards Development for EMF RF in Russia and by International Commissions: Distinctions in Approaches. In Markov, M (Ed.), Dosimetry in Bioelectromagnetics. Chapter 15. pp. 315-337. Boca Raton, FL: Taylor & Francis.
[92] Hankin, N. (2002). Letter from Norbert Hankin, U.S. Environmental Protection Agency, to Janet Newton President, The EMR Network (July 16, 2002), available at http://www.emrpolicy.org/litigation/case_law /docs/noi_epa_response.pdf .Accessed 21-03-2017.

[93] FCC (1999). Questions and Answers about Biological Effects and Potential Hazards of Radiofrequency Electromagnetic Fields. https://transition.fcc.gov/Bureaus/Engineering_Technology/Documents/bulletins/oet56/oet56e4.pdf

[94] https://www.businessinsider.com/apple-samsung-phones-fcc-investigation-excess-radiation-report-2019-8?r=US&IR=T

[95] Belyaev, I., Dean, A., Eger, H., Hubmann, G., Jandrisovits, R., Kern, M., ... & Oberfeld, G. (2016). EUROPAEM EMF Guideline 2016 for the prevention, diagnosis and treatment of EMF-related health problems and illnesses. Reviews on environmental health, 31(3), 363-397.

[96] BioInitiative Working Group, Sage C, Carpenter DO, editors. BioInitiative Report: A Rationale for Biologically-Based Public Exposure Standards for Electromagnetic Radiation (2012). Available from: http://www.bioinitiative.org

[97] Curry, B. (2000) Wireless LANs in the Classroom. A report to Dr. Gary Brown, Distance Learning, Senior Technical Specialist, Florida.

[98] URS (2012). RADIOFREQUENCY (RF) EVALUATION REPORT: Use of Wireless Devices in Educational Settings. Report to the Los Angeles Unified School District, Office of Environmental Health and Safety. http://nebula.wsimg.com/bd9036dad3575d0f8b21d68a33f752fb?AccessKeyId=045114F8E0676B9465FB&disposition=0&alloworigin=1

[99] http://www.lausd-oehs.org/docs/Misc/Radiofrequency_Safety_Fact_Sheet_021113a.pdf

[100] Mortazavi, S. J. (2018). Comments on "Wi-Fi radiation exposures to children in kindergartens and schools–results should lessen parental concerns". Australian and New Zealand journal of public health, 42(1), 112-112.

[101] Joseph, W., Pareit, D., Vermeeren, G., Naudts, D., Verloock, L., Martens, L., & Moerman, I. (2013). Determination of the duty cycle of WLAN for realistic radio frequency electromagnetic field exposure assessment. Progress in Biophysics and Molecular Biology, 111(1), 30-36.

[102] Peyman A, Khalid M, Calderon C, Addison D, Mee T, Maslanyj M, et al. (2011). Assessment of exposure to electromagnetic fields from wireless computer networks (Wi-Fi) in schools; results of laboratory measurements. Health Phys 100:594–612. doi:10.1097/HP.0b013e318200e203

[103] Khalid M, Mee T, Peyman A, Addison D, Calderon C, Maslanyj M, et al. Exposure to radio frequency electromagnetic fields from wireless computer networks: duty factors of Wi-Fi devices operating in schools. Prog Biophys Mol Biol (2011) 107:412–20. doi:10.1016/j.pbiomolbio.2011.08.004.

[104] Chiaramello, E., Bonato, M., Fiocchi, S., Tognola, G., Parazzini, M., Ravazzani, P., & Wiart, J. (2019). Radio Frequency Electromagnetic Fields Exposure Assessment in Indoor Environments: A Review. International journal of environmental research and public health, 16(6), 955.

[105] Di Ciaula, A. (2018). Towards 5G communication systems: Are there health implications?. International journal of hygiene and environmental health, 221(3), 367-375.

[106] Cajochen, C., Frey, S., Anders, D., Späti, J., Bues, M., Pross, A., Mager, R., WirzJustice, A., & Stefani, O., (2011). Evening exposure to a light-emitting diodes (LED)- backlit computer screen affects circadian physiology and cognitive performance. Journal of Applied Physiology 110, 1432e1438.

[107] Walker, M. P., and Stickgold, R. (2004). Sleep-dependent learning and memory consolidation. Neuron 44, 121–133. doi: 10.1016/j.neuron.2004.08.031

[108] Lobo, V., Patil, A., Phatak, A., & Chandra, N. (2010). Free radicals, antioxidants and functional foods: Impact on human health. Pharmacognosy reviews, 4(8), 118.

[109] Ikinci, A., Odaci, E., Yildirim, M., Kaya, H., Akça, M., Hanci, H., ... & Bas, O. (2013). The effects of prenatal exposure to a 900 megahertz electromagnetic field on hippocampus morphology and learning behavior in rat pups. NeuroQuantology, 11(4), 582-590.

[110] Narayanan, S. N., Kumar, R. S., Karun, K. M., Nayak, S. B., & Bhat, P. G. (2015). Possible cause for altered spatial cognition of prepubescent rats exposed to chronic radiofrequency electromagnetic radiation. Metabolic brain disease, 30(5), 1193-1206.

[111] https://www.cbsnews.com/news/parents-need-to-drastically-cut-kids-screen-time-devices-american-heart-association/

[112] https://www.lloyds.com/~/media/lloyds/reports/emerging%20risk%20reports/emf%20final%20november%202010.pdf

[113] https://www.swissre.com/dam/jcr:5916802c-cf6b-4c67-9d42-39cf80c4b00d/sonar-publication-2019.pdf

[114] Vodafone Group PLC, Annual Report 2012. https://www.vodafone.com/content /annualreport/annual_report12/downloads/performance_vodafone_ar2012_sections/principal_risk_factors_and_uncertainties_vodafone_ar2012.pdf.

[115] https://ecsfr.com.au/barrister-raymond-broomhall/
https://ecsfr.com.au/wp-content/uploads/2019/09/Raymond_Broomhall_Article_Website.pdf

[116] https://emfscientist.org/

[117] http://www.networkworld.com/article/3004112/ wi-fi/why-the-fccs-safety-guidelines-for-wi-fi-need-to-be-re-evaluated.html

[118] Tolgskaya, M.S. & Gordon, Z.V., (1973). Pathological Effects of Radio Waves, Translated from Russian by B Haigh. Consultants Bureau, New York/London 1-146.

[119] Glaser, Z., Brown, P.F., and Brown M.S. (1976). Bibliography of reported biological phenomena ("effects") and clinical manifestations attributed to microwave and radio-frequency radiation: Compilation and Integration of Report and Seven Supplements. Naval Medical Research Institute – National Naval Medical Center, Bethesda, USA. (see https://ehtrust.org/wp-content/uploads/Naval-MRI-Glaser-Report-1976.pdf)

[120] Miller, A. B., Morgan, L. L., Udasin, I., & Davis, D. L. (2018). Cancer epidemiology update, following the 2011 IARC evaluation of radiofrequency electromagnetic fields (Monograph 102). Environmental research, 167, 673-683.: //www.sciencedirect.com/science/article/pii/S0013935118303475

[121] http://www.5gappeal.eu/signatories-to-scientists-5g-appeal/

[122] https://en.wikipedia.org/wiki/Precautionary_principle

[123] Seattle Magazine 2011: https://www.seattlemag.com/article/uw-scientist-henry-lai-makes-waves-cell-phone-industry. An article on Professor Henry Lai.

[124] Hertsgaard, M & Dowie, M. (2018). The inconvenient truth about cancer and mobile phones. The Guardian, Sat 14 Jul 2018 15.00 BST. https://www.theguardian.com/ technolo.gy/ 2018/jul/14/mobile-phones-cancer-inconvenient-truths. Accessed Sunday 17th February, 2019.

[125] Zuboff, S. (2015). Big other: surveillance capitalism and the prospects of an information civilization. Journal of Information Technology, 30(1), 75-89.

[126] Turkle, S. (2017). Alone together: Why we expect more from technology and less from each other. Hachette UK.

[127] Taleb, N. N. (2007). The black swan: the impact of the highly improbable. London: Penguin.

[128] Taleb, N. N. (2012). Antifragile: how to live in a world we don't understand (Vol. 3). London: Allen Lane.